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A Further Consideration of Summit Ant Swarms

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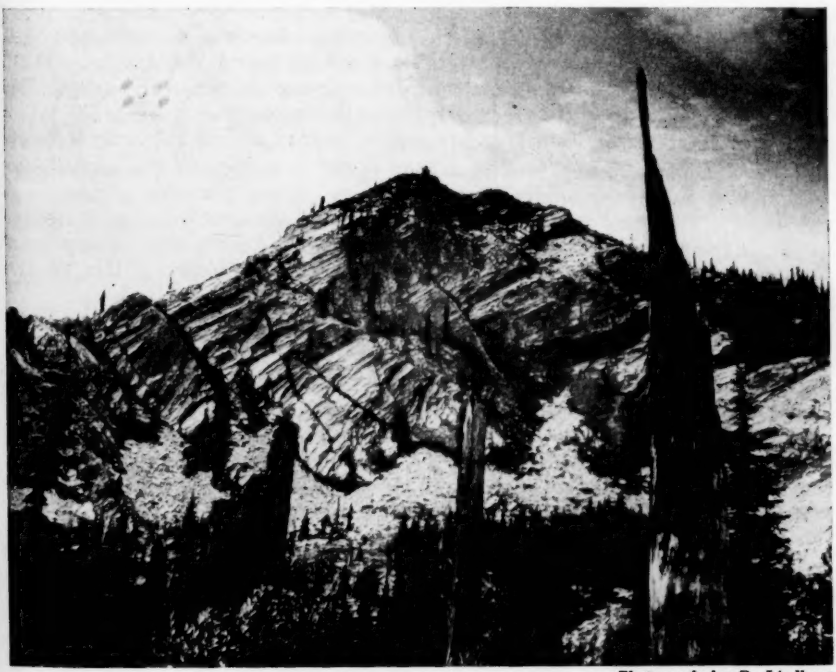
Introduction

An earlier report on summit ant swarms (Chapman, 1954b) presented data and observations based on first-hand studies and results from 256 questionnaires returned, in 1952, from observers at mountain-top fire lookout stations in the western U.S.A. (Fig. 1). In 1953, questionnaires were again sent to fire lookout observers, including some in western Canada, together with specimen boxes for samples from summit ant swarms. A total of 318 of these forms were returned, of which 235 were accompanied by samples of ants. This is a final report on the material supplied by lookout observers, together with a few additional comments on the phenomenon.

Generalizations from 1953 questionnaires

Many reports were incomplete and, as noted in the previous paper, caution must be used in interpreting the observations. The information supplied is considered valid, however, when many reports agree on some point or where



Photograph by R. Lindborg

Figure 1. Snow Peak (6,700 ft.), St. Joe National Forest (St. Maries, Idaho). Note lookout cabin at summit. This fire lookout station is a good example of the hundreds of mountain-top observation posts in western North America.

their detail and completeness indicate reliability. The reports present essentially the same picture as those of 1952 in regard to several features. These are: altitude and geographical distribution of summits represented, estimated sizes of swarms seen, times of swarming during the day and season, location of swarms at summits and particularly around prominent objects there, such as lookout towers or cabins, radio masts, etc., and the occurrence of the largest swarms during warm calm weather.

The form asked whether, in the opinion of the observer, ants appeared to be carried to the summit by air currents or flew there by choice. The replies were 21 for air currents, 186 for voluntary flight and five for both. Several observers added that they chose the voluntary flight because greatest numbers of ants appeared when the air was calm.

A reply was requested from lookout sites even if no ant swarming was seen, and there were 29 such responses, as compared with 289 reports of swarming. Some of the negative reports may have been due to absence of observers during swarming but probably most are valid. Certainly there are many factors affecting abundance of ants in areas surrounding summits. The fact remains that the great majority of lookout observers noticed, often for several consecutive years, one to several definite ant swarms a season at their mountain-top locations.

Comments by lookout observers

Some statements selected from lookout observer reports will help to give a picture of this phenomenon.

L. Geil, Schissler Peak (5,260 ft.), Bitterroot National Forest (Hamilton, Montana). "After breeding, the smaller males died and the heavier winged females dispersed. I have swept up approximately 10 gallons of dead ants from the floor after a heavy two to three hour swarm. Possibly 20 to 30 gallons of additional dead male ants would be heaped around the lookout base."

A. Goodgame, Seven Point Lookout (6,644 ft.), Cabinet National Forest (Thompson Falls, Montana). "As the days go by both species of ants – – grow more numerous and come earlier and leave later. The wind is always gentle, the temperature goes up and the humidity drops as the ants become more numerous. The ants, when any wind at all is blowing, always gather on the windless side of the lookout."

Mrs. V. Patton, Rocky Point (6,805 ft.), Lolo National Forest (Missoula, Montana). Mrs. Patton noted swarms there every year from 1942 to 1952, especially on hot dry days without wind. "They appear like a haze as they approach and sometimes are so thick they completely cover boards of building. - - At times they have been so numerous that the stove pipe on the building would have a foot or more of dead ants that came down and could not escape into the stove. Truly they are the most annoying thing that one has to contend with on these high places."

L. Woods, Forest Supervisor, Fishlake National Forest, Richfield Utah. "Several years ago I spent three summers on triangulation work and occupied many of the higher peaks in Western Wyoming and Central Idaho. I distinctly recall the flying ants as they were a decided nuisance when trying to do plane table and record work."

R. Moore, Pearsoll Peak (5,091 ft.), Siskiyou National Forest (Grants Pass, Oregon). "The ants swarm and mate here in the morning and leave in the afternoon – –. They swarm right on top of large rocks, small bushes and trees, also on top of the lookout – –."

Anon. Whisky Peak (6,500 ft.), Rogue River National Forest (Medford, Oregon). "About 8:00 a.m. they start assembling around the tips of a few fir trees that grow on the north side and whose tops are a few feet higher than the peak itself. As soon as air warms sufficiently (usually around 9:00 a.m.) they start moving toward building – –. They seem to be especially attracted to smoke stack."

P. Clapp, Devil's Peak (5,054 ft.), Mt. Hood National Forest (Portland, Oregon). Aug. 9, 1952 "The largest swarm seen so far arrived this morning. – – there must have been literally tens of thousands. It is a bright warm (70°F.) day with little wind – –. The ants were seen not only around the lookout house but also (by binoculars) in the tops of several large trees in the vicinity. The trees are down-slope, and so their tops are slightly below the tower level."

L. Turville, Larch Mt. (4,045 ft.), Mt. Hood National Forest (Portland, Oregon). "In the mornings the ants would swarm up from all sides of the tower regardless of wind direction or velocity. The ants would seem to come up out of the trees, then angle toward the top of the tower."

Mrs. A. Donnelly, Silver Star Mt. (4,500 ft.), Gifford Pinchot National Forest (Vancouver, Washington). July 17, 1952, clear and calm and 70°F. at 7:00 a.m. when ants started to appear. "The swarm increased and a steady stream 10-12 feet wide were flying – – in a straight line from the direction of the rocky butte, Pyramid Rock, two miles southwest of Silver Star. This – – flight continued for three hours. – – By 9:00 a.m. a new swarm was noticed advancing in a steady oncoming flight from the west in a direct line from the rocky butte, Sturgeon Peak, one half mile to the west of Silver Star. By 9:30 to 10:00 a.m. – – the roofs and shutters were crawling, seething masses of working ants, some mating, some flying around the nearby roof area. The swarming was virtually over by 11:30 a.m."

L. Letourneau, Coliseum Lookout (6,690 ft.), Nordeg, Alberta. Noted swarms there for ten years although none were seen in 1953, presumably because of excessive rain. "I always found that the ants will gather on a large black cloth or object if it is put as high as possible."

A. Muchmore, District Forest Ranger, Dillon, Montana. Referring to a swarm seen in 1952, "They were observed along a long, open ridge of Continental Divide. They swarmed around my head and about the horse I was riding along the crests of the ridge."

M. James, District Forest Ranger, Escondido, Calif. Referring to 1938, Cinnabar Peak (7,000 ft.), Lolo National Forest (Missoula, Montana). "Flying ants here became a real problem. They seemed to prefer to swarm on my tent which was white and other white objects such as the rain gage. Since I had no closed tower or cab they got into everything. – – I started experimenting and finally found that by placing a white rag on a pole and raising it above the elevation of the tent that the ants preferred the rag as a collection point and left the tent alone."

Finally, several persons have mentioned that in lowland areas in Montana winged ants are at times annoying because they swarm above haystacks and crawl in numbers on men working there.

Species of summit-swarming ants

The distribution picture of summit-swarming species is limited by the location of summit lookout stations. These are not used in many parts of the Rocky Mountains; Utah and portions of Colorado and Arizona, for example.

Information on species participation in summit swarms is also incomplete because of the difficulty of making reliable determinations from sexual forms alone. The groups reported swarming at five or more summits in 1953 and the number of summits from which they were taken are as follows:

Formica subnuda Emery	128
Formica sp. (*subnuda* Em.?)	9
Formica sp., *microgyna* group	15
Formica sp.	41
Leptothorax canadensis Provancher br. sense	76
Leptothorax sp.	12
Myrmica lobicornis fracticornis Emery	15
Myrmica (*Myrmica*) sp.	55
Pogonomyrmex occidentalis (Cress.)	8
Pogonomyrmex sp.	11

F. subnuda and *L. canadensis* were most frequently collected (often from the same peak) as indicated by the 1952 report. *M. lobicornis fracticornis*, *P. occidentalis* and certain other species apparently swarm at summits also. The geographical distribution of these groups is given by Creighton (1950).

Samples of *F. subnuda* were collected from swarms at many summits within its expected range, from Arizona and New Mexico through Idaho and Montana to Alberta. In addition, specimens were collected at four peaks in the Black Hills of South Dakota (Custer and Hill City); 27 peaks in California, from the central part of the Sierra Nevadas (North Fork, Big Creek) northward (e.g., Alturas, Dunsmuir, McCloud, Mariposa, Redding, Weaverville); 17 peaks in Oregon, mostly in the western part (e.g., Bly, Crescent, Foster, Gold Beach, Oakridge); and 19 peaks in Washington (western, central and eastern parts of the state being represented (e.g., Quilcene, Port Angeles, Leavenworth, Twisp, Colville, Metaline Falls). The species is therefore distributed more widely than usually reported. This is not surprising, however, considering its adaptability (it nests in a variety of sites) and the general similarity of environments in the Rockies and other western mountains.

L. canadensis was returned mostly from points within its reported range. It was also sent from three locations in Arizona (Safford, Springeville, Freedonia) and three in California (Hayfork, Chico, Greenville). The samples of *M. lobicornis fracticornis* came from expected areas (Alberta, Idaho, Montana, Oregon, Washington) and also from two California localities (North Fork, Dunsmuir). *P. occidentalis* was returned from localities in Colorado, New Mexico and Oregon, within its described range.

With respect to altitudinal distribution, Hoff (personal communication, 1957) gives the following information for northern and central New Mexico:

L. canadensis yankee. Common, taken from 6,600 to 12,300 ft.

M. lobicornis fracticornis. Common, taken from 7,000 to 12,000 ft. Highest altitudes are around timberline.

P. occidentalis. Common between 4,000 and 9,000 ft.

(data on *Formica* are not yet available).

The former two species, particularly, could occur in numbers near many mountain tops in that area.

Gregg (1947), in his preliminary report on ants in relation to altitude in Colorado, listed *L. canadensis* from Canadian, Hudsonian and Alpine zones, *F. subnuda* as more abundant in the Transition zone (foothills) and *P. occidentalis*, the prairie harvester ant, as an Upper Sonoran (plains) species. Further studies

have shown, however, (Gregg, personal communication, 1957), that *F. subnuda* is most often found at higher altitudes (the majority of his records are from 8,000 to 10,000 ft.) and is conspicuous in the Canadian and Hudsonian zones. Thus, *F. subnuda*, also, would be expected to nest near many Rocky Mountain summits.

It is more difficult to explain swarms of *P. occidentalis* on mountain tops, although there is little doubt that they occur. Four of eight returns of this species described its numbers as 10,000's and such concentrations at summits could hardly be due to wind alone. It was taken in several states, from swarms on peaks of the following altitudes (in feet): 7,077 (Montana); 8,100 (Colorado); 9,665 (Wyoming); 6,000, 7,455 (Oregon); 7,700, 8,620, 8,000-9,000 (est.) (New Mexico. *P. occidentalis* was never taken from the same location as *L. canadensis* and only once where *F. subnuda* also congregated. This suggests different ecological conditions around summits where the former swarmed as compared with those around peaks where the two other species gathered. Even the Upper Sonoran zone extends above 6,000 feet in parts of the western U.S., and summits occur at low as well as at high altitudes, of course. In view of these factors and Hoff's records on this species it can be concluded that even *P. occidentalis* finds suitable habitats, due to combinations of slope, exposure and other factors, near many western U.S. mountain summits.

Discussion

I would like first to mention a few observations by others that bear on the general question of summit insect activity and were not referred to by Chapman (1954a,b) or Dodge and Seago (1954). Rawlings (1948) reported swarming of *Sirex noctilio* males about tops of the highest trees in an area and later (personal communication, 1956) mentioned that they also flew about hill summits in numbers. There is a recent series of observations on activity of certain butterflies on summits (see Beall, 1953; Guppy, 1953). Fosberg (1955) recorded observations on swarming of ants on a New Mexico mountain top. He also described preference of the ants for prominent objects on summits, including isolated yuccas, a windmill and surveying equipment. Of most significance, however, is the report by Schneider (1952) on extensive studies of flight orientation of the May beetle, *Melolontha*. It has been found that these beetles often show well-defined flight paths and consistent flight directions past a given point and concentrate at certain places at or within forest margins. After analysis of much data Schneider concludes that on their pre-alimentary flight the beetles orientate toward the highest, or most prominent, silhouette on the horizon. He calls this behaviour "hypsotaxis" (hypsos-high), "Orientierung nach der höchsten Silhouette" (see also Couturier and Robert, 1955).

It appears to me, considering available evidence, that swarming of winged ants on summits must result from a type of behaviour in which they follow a visual cue to an assembling point. Their behaviour is probably similar to that of many midges and mosquitoes which are known to gather over "swarm-markers", including men, trees and other prominent objects (e.g., Bates, 1949; Frohne, 1953; Downes, 1955). Once formed, a large swarm of insects could itself represent a prominent object. The same response which could lead winged ants to a small object such as a bush, tree or building in some situations could lead them to the top of a nearby hill or peak in others. A summit within a mile or so, or a much smaller object nearby, would presumably each represent a conspicuous silhouette on the horizon. Actually, long ago Forel (1874) mentioned swarming of winged ants over a number of prominent objects which varied considerably in size, "– en prenant presque toujours pour base un objet

élevé au-dessus de terre, ainsi le clocher d'une église, le sommet d'un peuplier, le haut d'une colline ou même d'une montagne".

As mentioned earlier the two species most frequently represented in western U.S. summit swarms are mountain ants. If their nests were fairly abundant near mountain-tops any behaviour of the reproductives equivalent or similar to the "hypsotaxis" shown by *Melolontha* could lead them to the summits in large numbers, and, further, to objects there such as lookout towers or rock piles. It is well to note, as recognized by Schneider, and Couturier and Robert, that a "skototaxis" might be involved in such a response.

Presumably, other insects known to frequent prominent objects including summits show similar behaviour. The role of meteorological conditions, particularly the distribution of gentle currents of warm air about summits on certain days should not be ignored as a factor in summit insect concentrations. However, beyond the well known fact that strong updrafts are common in mountainous country there is little information of this type to consider at present.

Hill or mountain tops represent well-defined meeting places for the two sexes and it would seem advantageous to certain ant species, depending on their ecology and habits, to have definite meeting points. On the other hand, mountain summits are usually poor nesting sites because of their rocky nature, poor soil, altitude and exposure. A question thus arises, as recognized in the previous report, as to the behaviour of females after mating at summits. Do they stay and perish in futile attempts to establish nests, or do they continue to fly for a period after mating, thereby leaving the summit area? It is likely that where large numbers of winged ants swarm around lookout buildings, loss of wings would be noticed if frequent. Of 77 observers (1952 and 1953) reporting swarms in 10,000's (rather than 1,000's or 100's) and answering the question on wing shedding, ten reported loss of wings to occur, five others saw only a slight amount while 62 said they saw none. These figures, as well as my own observations (1954b), indicate lack of general wing shedding at summits. It thus appears that most females of summit-swarming species fly down from a summit, after mating, before trying to establish nests. This would, theoretically, be an expected part of any summit swarming behaviour pattern. There is need, however, for further investigation of this important point.

The view that mountain-or hill-top concentrations of winged ants of certain species are due directly to their own activity need not conflict with the assumption, supported by many observations, that in mountainous country winged ants as scattered individuals are often carried by air currents to high altitudes entirely unsuitable for nest sites (e.g., Wheeler, 1917; Gregg, 1947). The present study deals with definite swarms of ants. These swarms, moreover, were reported mostly from peaks of such altitudes that ants could easily have flown there from nest sites without assistance from wind. For example, the combined 1952 and 1953 reports represented 315 summits below and 63 above 8,000 ft., many of the latter being in the southwest where timberline is higher. This altitude is below timberline for most of the U.S. Rocky Mountains (Griggs, 1938) even though lower summits are frequently bare (note Fig. 1).

In conclusion, an explanation for summit ant swarms is presented which views the phenomenon as a result of behaviour involving orientation toward an object prominent on the horizon. It remains for experimental studies to support or refute this explanation.

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Peak. A large number of persons, most of them employees of the U.S. Forest Service, co-operated in securing information on summit ant swarms and I regret that their help cannot be individually acknowledged here. I am particularly grateful to Dr. M. R. Smith, U.S. National Museum, for identifying the specimens, all sexual forms. I also thank Mr. R. R. Lejeune, Forest Biology Laboratory, Victoria, for reading the manuscript, Dr. R. E. Gregg, Univ. of Colorado, Boulder and Dr. C. Hoff, Univ. of New Mexico, Albuquerque, for supplying unpublished information on altitudinal distribution of ants in their study areas, and my wife for much help in correspondence and handling reports and specimens.

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Distributional Notes on and Synonymies of Some North American Scolytidae (Coleoptera)[1]

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This paper introduces new names and synonymies to North American workers and corrects a few errors in the literature involving North American species of Scolytidae. A few distributional records are included to support some of the proposed synonymies. For convenience of reference the names of the species involved are arranged alphabetically.

Crypturgus borealis Swaine

Crypturgus borealis Swaine, 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 7.
Crypturgus corrugatus Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 8.

The cotypes of Swaine's *borealis* and *corrugatus* in the Canadian National Collection are callow and in rather poor condition, but direct comparison of his type series and of other series from eastern North America indicated that only one species is represented. The species is rather well known in the western parts of its range but eastern records are comparatively rare. New eastern records include the following:—*New Brunswick*: Miramichi, June 16, 1921, J. D. McFarlane; and Nictor Lake, July 4, 1921, red spruce, M. B. Dunn. *Quebec*: Gaspé July 1922 G. S. Fleming; and Trinity Bay Sept. 23, 1929, *Abies balsamea*, E. B. Watson. *Ontario*: Ottawa, Mar. 22, 1914, J. I. Beaulne. Manitoba: Aweme, July 6, 1920, N. Criddle. *New York*: Heart Lake, Essex County, Aug. 23, 1940, H. Dietrich.

Cryptocarenus heveae (Hagedorn)

Stephanoderes heveae Hagedorn, 1912, Rev. Zool. Africaine 1: 338.
Cryptocarenus porosus Wood (new synonymy), 1954, Univ. Kansas Sci. Bull. 36: 1014.

A series of African specimens studied recently included variations similar to those observed in the Florida specimens described as *porosus*. The presence of several other African species in southern Florida supports the suspected synonymy.

Dendroctonus parallelocollis Chapuis

Dendroctonus parallelocollis Chapuis, 1869, Synopsis des Scolytides, p. 36.
Dendroctonus approximatus Dietz, 1890, Trans. Amer. Ent. Soc. 17: 31.

Schedl (1955, Zeit. angewandte Ent. '38:11) was correct in synonymizing *parallelocollis* and *approximatus*.

Hexacolus schwarzi (Hopkins)

Erineophilus schwarzi Hopkins, 1903, Proc. Ent. Soc. Washington 5: 34.

The species *schwarzi* was correctly transferred from the genus *Erineophilus* Hopkins to *Hexacolus* Eichhoff by Schedl (1952, Dusenia 3:346). The monotypic genus *Erineophilus* (1903), therefore, becomes a synonym of *Hexacolus* Eichhoff (1867).

Hylastes nigrinus (Mannerheim)

Hylurgus nigrinus Mannerheim, 1852, Bull. soc. imp. nat. Moscou 25: 356.
Hylastes yukonis Fall (new synonymy), 1926, Pan-Pacific Ent. 2: 207.

A series of specimens bearing exactly the same data as Fall's type of *yukonis* consisted of typical northern specimens of Mannerheim's species *nigrinus*. Blackman (1941, U.S. Dept. Agr. Misc. Pub. 417:14) had suspected this, but had seen no authentic specimens of Fall's species.

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Hylurgops incomptus (Blandford)

Hylastes incomptus Blandford, 1897, Biol. Centr. Amer., Coleoptera 4(6): 145.
Hylurgops grandicollis Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 17.

Blandford's species *incomptus* is rather common and widely distributed in the coniferous forests of Mexico. Since its range is continuous with that of Swaine's *grandicollis*, and in the absence of morphological or host differences, Swaine's name *grandicollis* must be placed in synonymy with the older name *incomptus* Blandford. In part, this conclusion was based on direct comparisons of Swaine's type with several specimens labelled *incomptus* by Eggers and Wood.

Ips bonanseai (Hopkins)

Tomicus bonanseai Hopkins, 1906 (1905), Proc. Ent. Soc. Washington 7: 76.

This abundant and widely distributed Mexican species has not been reported previously from the United States. Series from the Santa Rita Mountains, Arizona, collected by H. F. Snow, and from the Chiricahua Mountains, Arizona, were examined.

Ips concinnus (Mannerheim)

Bostrichus concinnus Mannerheim, 1852, Bull. soc. imp. nat. Moscou 25: 358.
Ips chamberlini Swaine, 1925, Can. Ent. 57: 196.

The synonymy of *concinnus* (Mannerheim) and *chamberlini* Swaine was correctly proposed by Schedl (1955, Zeit. angewandte Ent. 38:34), although he evidently had not examined the type of either species. Swaine's *chamberlini* was described from a short series taken in *Pseudotsuga taxifolia*, obviously an abnormal host according to the collector's notes; examination of the type in the Canadian Collection indicated that it was a normal specimen of *concinnus*.

Ips confusus (Leconte)

Tomicus confusus Leconte, 1876, Proc. Amer. Philos. Soc. 15: 364.

This species occurs in Oregon, California, Nevada, Utah, Arizona, New Mexico, and western Texas; specimens from Mexico were not examined, but it doubtless occurs there. Its distribution overlaps those of both *montanus* (Eichhoff) and *lecontei* Swaine; the three species can be easily segregated by morphological characters. Schedl (op. cit., p. 40) grouped four species, *lecontei*, *montanus*, *cloudcrofti*, and *confusus*, under the name *confusus* (Leconte).

Ips cribricollis (Eichhoff)

Tomicus cribricollis Eichhoff, 1869 (1868), Berl. ent. Zeit. 12: 273.
Ips cloudcrofti Swaine (new synonymy), 1924, Can. Ent. 56: 70.

Several series of this Mexican species, bearing the identification labels of Eggers, Schedl, and Wood, were compared with Swaine's type series of *cloudcrofti* in the Canadian National Collection and were identical in all respects. Schedl (op. cit., p. 40) considered *cloudcrofti* as a synonym of the much larger species *confusus;* he evidently had not seen the type.

Ips englemanni Swaine

Ips englemanni Swaine, 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 30.
Ips dubius Swaine (new synonymy), 1918, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(2): 119.

The type and several paratypes of *dubius*, all males, were taken in the same galleries as the type series of *englemanni*, all females. Other paratypes of *dubius*, all males, were taken with the type series of the allied species *yoboensis* Swaine, all females. Comparison of these series with others of the complex taken more recently showed that the type of *dubius* was a male of *englemanni*.

Ips lecontei Swaine

Ips lecontei Swaine, 1924, Can. Ent. 56: 70.

This is a valid species allied to *grandicollis* (Eichhoff); it is not a synonym of *confusus* as suggested by Schedl (op. cit., p. 40). The position of the first declivital tooth and characters of the male genitalia distinguish it from *confusus*. Specimens, including the type, were examined from several localities in Arizona and Mexico.

Ips mexicanus (Hopkins)

Tomicus mexicanus Hopkins, 1906 (1905), Proc. Ent. Soc. Washington 7:75.

Schedl (op. cit., p. 34) placed this species in synonymy with *concinnus*; however, there are differences in gallery pattern, in distribution of attack on a host tree, and in host preference. Their biologies should be thoroughly understood before synonymy is proposed.

Ips montanus (Eichhoff)

Tomicus montanus Eichhoff, 1880 (1881), Die europäischen Borkenkäfer, p. 219.
Ips vancouveri Swaine (new synonymy), 1916, Can. Ent. 48: 188.

About 1920 Swaine borrowed several collections of *Ips* material for an intended revision of the genus. Part of this material, for a variety of reasons, was not returned. Since a few types were included in the borrowed material, a specimen bearing the type data and labelled "Type", in Eichhoff's hand, obviously from the type series, possibly is the type of *Tomicus montanus* Eichhoff. Eggers had studied the type, had corresponded with Swaine, and had been visited by Swaine about the time of Swaine's interest in the genus. Since the Eichhoff collection has been largely destroyed, and with it the remainder of the type series of *Tomicus montanus*, the specimen at hand is, or presumably should be, the type of the species. Comparison of this specimen and several of Eggers' homotypes of *Tomicus montanus* with Swaine's type series of *vancouveri* indicated that only one species is represented.

The specimens in Eichhoff's type series were labelled either "Cal." or "Cisco." Eggers (1933, Ent. Nachr. Bl. 7:20) suggested that "Cisco" might refer to a town in Texas or to San Francisco, California. Since the species does not occur in Texas, or in California anywhere near San Francisco, at least those specimens labelled "Cisco" were probably taken at Cisco, British Columbia, the only locality known as Cisco within the distribution of the species. Specimens were examined from British Columbia, Idaho, (?) Montana, and California (the high mountains of Lassen County and Yosemite Park); they are larger than specimens of *confusus* and, in the male, differ conspicuously in frontal sculpture. Schedl (op. cit., p. 40) considered both *montanus* and *vancouveri* as synonyms of *confusus*.

Ips pini (Say)

Bostrichus pini Say, 1826, J. Acad. Nat. Sci. Philadelphia 5: 257.
Ips laticollis Swaine (new synonymy), 1918, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(2): 116.

The series named *laticollis* by Swaine does not differ in any respect from normal specimens of *pini*. Swaine indicated in the original description that this might be the case. In the absence of observable differences in morphology, hosts, or distribution the name *laticollis* Swaine must be placed in synonymy with the older name *pini* (Say).

Ips plastographus (Leconte)

Tomicus plastographus Leconte, 1868, Trans. Amer. Ent. Soc. 2: 163.
Tomicus integer Eichhoff, 1869 (1868), Berl. ent. Zeit. 12: 273.

Several writers, including Schedl (op. cit., p. 43), have recognized the synonymy of these names; however, most of them have failed to recognize that

the name *plastographus*, validated in September of 1868, has priority over the name *integer*, validated in March of 1869.

Ips radiatae Hopkins

Ips radiatae Hopkins, 1915, Proc. Ent. Soc. Washington 17: 54.

Schedl (op. cit., p. 34) placed this name in synonymy with *concinnus*; however, there appear to be differences in gallery pattern, in distribution of attack on a host tree, and in host preference. Their biologies should be thoroughly understood before synonymy is proposed.

Leperisinus aculeatus (Say)

Hylesinus aculeatus Say, 1826, J. Acad. Nat. Sci. Philadelphia 3: 322.
Leperisinus cinereus Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 15.

Swaine's *cinereus* was described from five specimens representing four localities. In addition to the scale colour the characters he used were: " . . . somewhat stouter with the elytra more convex at the middle; . . . pronotal surface less strongly rugose; the elytral striae wider and distinct, the interstrial asperities much smaller . . . ." All of these characters, except colour, apply equally well to the average specimen of *aculeatus* collected in eastern Canada. A long series of an allied species, *criddlei* Swaine, was examined recently in which the colour pattern varied from normal to complete absence. The scales of specimens in which the colour pattern did not develop were white, giving exactly the same appearance as observed in Swaine's *cinereus*. Since Swaine's type specimen of *cinereus* was "found first among material of *aculeatus* taken from ash", and since his long series of *aculeatus* from Ste. Anne de Bellevue, Quebec, contains specimens with all gradations of colour pattern from normal to near absence (the one with no colour pattern was assigned to *cinereus*), it must be concluded that the absence of colour pattern in these species is a normal variation. The name *cinereus* Swaine, therefore, must be placed in synonymy under the older name *aculeatus* (Say).

Liparthrum squamosum (Blackman), new combination

Erineosinus squamosus Blackman, 1920, Mississippi Agr. Expt. Sta. Tech. Bull. 9: 53.

Blackman described the monobasic genus *Erineosinus* for this species, and treated it in his classifications of the subfamily Micracinae in 1920 and 1928. It was omitted, without explanation, from his latest classification of the group (Blackman, 1943, Proc. U.S. Natl. Mus. 93:341-365). He described the antennal funicle as being five-segmented in the female, four-segmented in the male. However, of seven specimens examined by the present writer, one had five segments and six had four segments, the number not being associated with sex. This new information indicates that *Erineosinus* is a synonym of the Old World genus *Liparthrum;* the species *squamosum* is very similar to *mori* Aubé. The distributional pattern suggests that the North American species has been introduced to this continent; however, it has not yet been identified in the Old World Fauna, where the remainder of the species in the genus occurs.

Micracis swainei Blackman

Micrasis swainei Blackman, 1920, Mississippi Agr. Expt. Sta. Tech. Bull. 9:32.
Micrasis populi Swaine (new synonymy), 1920, *in* Blackman, Mississippi Agr. Expt. Sta. Tech. Bull. 9: 31.

The type series of *populi* and a paratype of *swainei* were compared directly; in addition, the type of *swainei* and numerous series from the eastern half of the United States were studied. The type and one or two paratypes of *populi*, amounting to about a third of Swaine's series, exhibit an abnormality in the outline of the antennal club. Since his specimens were callow it is presumed that

the shape of the club changed as they dried, thereby accounting for its extremely slender outline. Although Swaine's name has page priority, it is proposed that Blackman's name *swainei* be used for this species, because (a) the principal characters on which Swaine's species was established were abnormal; (b) Swaine's description was included, as a gesture of courtesy, in Blackman's paper; it is doubtful that it would ever have appeared had this not been done; and (c) both authors are given a measure of recognition if Blackman's name *swainei* is used.

Phloeosinus antennatus Swaine

Phloeosinus antennatus Swaine, 1924, Can. Ent. 56: 146.
Phloeosinus pseudotsugae Chamberlin (new synonymy), 1955, Pan-Pacific Ent. 31: 117.

Paratypes of Chamberlin's *pseudotsugae* were compared with the type series of *antennatus* and are morphologically identical. Although Douglas fir is not the usual host of this species, host difference without supporting evidence does not warrant recognition of a distinct species in this genus. Unusual host records, such as the above, are uncommon in *Phloeosinus*, but certainly not unknown. It is, therefore, proposed that Chamberlin's name *pseudotsugae* be placed in synonymy with *antennatus* Swaine.

Phloeosinus pini Swaine

Phloeosinus pini Swaine, 1915, Can. Ent. 47: 362.
Phloeosinus piceae Swaine (new synonymy), 1934, Can. Ent. 66: 205.

The type series of both *pini* and *piceae*, and a long series labelled *piceae* by Swaine, were compared directly. The frontal concavities of males in the long series varied slightly in depth and width, but no more than the types of *pini* and *piceae* and no more than in some other species of the genus; these males were identical with the types of both *pini* and *piceae* in all other respects. Since other species in the genus commonly breed in host species belonging to several genera, the host differences in this case are not sufficient to warrant the recognition of two species. The pronotum is distinctly wider than long in both sexes, although it was reported to be longer than wide in the female of *piceae* by Blackman (1942, Proc. U.S. Natl. Mus. 92:400).

Phloeosinus sequoiae Hopkins

Phloeosinus sequoiae Hopkins, 1903, U.S. Bur. For. Bull. 38: 33.
Phloeosinus squamosus Blackman, nec Schedl (new synonymy), 1942, Proc. U.S. Natl. Mus. 92: 448.
Phloeosinus blackmani Schedl (new synonymy), 1950, Occ. Papers B. P. Bishop Mus. 20: 36.

Several dozen series of this species collected from British Columbia to southern California were studied. What Blackman believed to be allopatric species represent only segments in a continuous distribution. The differences in vestiture used by Blackman in separating his *squamosus* from *sequoiae* appear to depend on age of the specimen; the differences in declivital punctation may be individual variations of a single series, although occasionally an entire series has this area either finely punctured or is almost devoid of punctures, this variation being independent of geographical origin of the specimens. In the absence of consistent morphological or host differences, and in view of the continuous distribution, only one species can be recognized.

Pityogenes plagiatus (Leconte)

Xyleborus plagiatus Leconte, 1868, Trans. Amer. Ent. Soc. 2: 161.
Pityogenes lecontei Swaine (new synonymy), 1915, Syracuse Univ., Coll. For. Tech. Pub. 2: 10.

Swaine's type series of *lecontei* was composed of typical examples of *plagiatus*. In his collection he had only a short series labelled *plagiatus* and the

females among these specimens were in poor condition. In view of this misidentification the name *lecontei* Swaine must be placed in synonymy under the older name *plagiatus* (Leconte).

***Pityokteines minutus* (Swaine)**

Dryocoetes minutus Swaine, 1912, Can. Ent. 44: 352.
Pityokteines jasperi Swaine (new synonymy), 1916, Can. Ent. 48: 181.

The validity of *jasperi* was questioned by Swaine at the time he described it. The characters used to differentiate between *minutus* and *jasperi* are obscure, at best, and since both were taken from *Abies lasiocarpa* and the distributions are continuous, the only conclusion possible is that only one species is represented.

***Pityophthorus borealis* Swaine**

Pityophthorus borealis Swaine, 1925, Can. Ent. 57: 195.
Pityophthorus varians Schedl (new synonymy), 1930, Can. Ent. 62: 196.

The types, including series of paratypes, of both *borealis* and *varians* were compared directly. Schedl's series consisted entirely of males; consequently, he associated it with Blackman's "Group Four" of the genus instead of "Group One", where it should be placed. In the absence of morphological or host differences between the two, and in view of the transcontinental distribution of several other northern species, the name *varians* Schedl must be placed in synonymy under the older name *borealis* Swaine.

***Pityophthorus concentralis* Eichhoff**

Pityophthorus concentralis Eichhoff, 1878, Mem. soc. roy. sci. Liége, ser. 2, 8: 188.
Pityophthorus lateralis Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 27.

Comparison of Swaine's type of *lateralis* with several long series of *concentralis* indicated that *lateralis* represented only a very minor variation found in almost any long series of the species. In the absence of significant morphological differences, or of other species near Key West, Florida, that could be confused with it, Swaine's name *lateralis* must be placed in synonymy under the older name *concentralis* Eichhoff. One of Swaine's two specimens of *concentralis* that were used in fixing the identity of this species appears to have been identified by Eichhoff (evidently received through Schwarz).

***Pityophthorus murrayanae* Blackman**

Pityophthorus murrayanae Blackman, 1922, Syracuse Univ., Coll. For. Tech. Pub. 16: 138.
Pityophthorus tenuis Swaine (new synonymy), 1925, Can. Ent. 57: 196.

The type and a paratype of *elongatus* Swaine, recognized by Blackman as a synonym of *murrayanae*, were compared with the type of *tenuis* and with an example of *murrayanae* that had been examined by Blackman. The types of *elongatus* and *tenuis* appear identical morphologically; they also bear the same locality labels and lot number, although the sublot numbers are different. The morphological differences between *murrayanae* and *tenuis* that were pointed out by Blackman (1928, Syracuse Univ., Coll. For. Tech. Pub. 25:134) cannot be seen in the material at hand. The name *tenuis* Swaine, therefore, must be recognized as a synonym of the older name *murrayanae* Blackman.

***Pityophthorus opaculus* Leconte**

Pityophthorus opaculus Leconte, 1878, Proc. Amer. Philos. Soc. 17: 623.
Pityophthorus pygmaeus Schedl (new synonymy), 1931, Can. Ent. 63: 165.

Schedl's type series of *pygmaeus* appears to have been selected from a longer series of *opaculus* that is in the Swaine collection; the lot numbers on the specimens are identical, and no other data appear on the labels. The form *pygmaeus* Schedl obviously represents no more than a normal variation in size.

***Pseudothysanoes rigidus* (Leconte)**

Cryphalus rigidus Leconte, 1876, Proc. Amer. Philos. Soc. 15: 362.
Pseudothysanoes drakei Blackman (new synonymy), 1920, Mississippi Agr. Expt. Sta. Tech. Bull. 9: 48.

Several series of *rigidus*, part of them examined by Blackman, were compared with paratypes of *drakei* and are morphologically identical. The characters used by Blackman in separating the two represent no more than normal variations in the long series; the hosts are the same and the distributions continuous.

***Premnobius cavipennis* Eichhoff**

Premnobius cavipennis Eichhoff, 1878, Mem. soc. roy. sci. Liége, ser. 2, 8: 404.

This African species is now widely distributed in the New World. Collection records indicate that it has occurred in Florida for many years, but has not previously been reported. Specimens from the following localities in Florida were examined: Homestead, Miami, Plant City and Sanford. All specimens were taken at light, except one that was taken in an old mangrove branch. The genus is allied to *Xyleborus;* the habits also appear similar to those of representatives of that genus.

***Pycnarthrum hispidum* (Ferrari)**

Hypoborus hispidus Ferrari, 1867, Die Forst- und Baumsuchtschädlichen Borkenkäfer, p. 19.

This species was described from Cuba, but has not been reported previously from continental America. Specimens were collected in Florida as follows: Royal Palm State Park, July 21, 1945, at light, R. H. Beamer; Perrine, June 22, 1951, at light, and Sugar Loaf Key, July 3, 1951, *Ficus aurea*, S. L. Wood; and Perrine, July 24, 1951, at light, F. G. Butcher.

***Renocis heterodoxus* Casey**

Renocis heterodoxus Casey, 1886, Bull. California Acad. Sci. 2: 258.
Pseudocryphalus brittaini Swaine (new synonmy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 20.
Pseudocryphalus criddlei Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 21.

The type of Swaine's *brittaini* and *creddlei* were compared with several series of Casey's *heterodoxus* from various widely separated parts of its distribution, including Oregon, Utah, Colorado, and Arizona. Since Swaine's species do not exhibit morphological differences not normally found in these long series of *heterodoxus*, since their distributions are continuous with that of *heterodoxus*, and since the hosts of Swaine's species are normal ones of *heterodoxus*, evidently only one species is represented.

***Stephenoderes birmanus* (Eichhoff)**

Triarmocerus birmanus Eichhoff, 1878, Mem. soc. roy. sci. Liége, ser. 2, 8: 486.
Stephanoderes castaneus Wood, 1954, Univ. Kansas Sci. Bull. 36: 1027.

The name *castaneus* Wood is a synonym of *Triarmocerus birmanus* (Eichhoff), an oriental species. The details concerning this synonymy were discussed by the writer in "The Insects of Micronesia, Coleoptera: Platypodidae and Scolytidae" (in press).

***Stephanoderes javanus* Eggers**

Stephanoderes javanus Eggers, 1908, Ent. Bl. 4: 215.
Stephanoderes obesus Hopkins (new synonymy), 1915, U.S. Dept. Agr. Rept. 99: 30.
Stephanoderes philippinensis Hopkins (new synonymy), 1915, U.S. Dept. Agr. Rept. 99: 31.

The types of Hopkins' *obesus* and *philippinensis* were compared with the portion of the type species of *javanus* in the Eggers collection at the U.S. National Museum. Morphologically they appear to represent one species. The dis-

tribution of this species is now similar to that of a number of species that have spread throughout the suitable tropical and subtropical habitats of the world in comparatively recent years.

***Xyleborus ferrugineus* (Fabricius)**

Bostrichus ferrugineus Fabricius, 1801, Syst. Eleuth. 2: 388.
Xyleborus fuscatus Eichhoff, 1867, Berl. ent. Zeit. 11: 400.
Xyleborus confusus Eichhoff, 1867, Berl. ent. Zeit. 11: 401.

The details concerning this synonymy were discussed by the writer in "The Insects of Micronesia, Coleoptera: Platypodidae and Scolytidae" (in press).

***Xyleborus (Anisandrus) pyri* (Peck)**

Scolytus pyri Peck, 1817, Massachusetts Agr. J. 4: 205.
Anisandrus swainei Drake (new synonymy), 1921, Ohio J. Sci. 21: 203.

Drake's species *swainei* was based on differences from *pyri* (Peck) in body form, in shape of the pronotum, and in the declivital striae. Since the paratypes of *swainei* in the Canadian National Collection, sent to Swaine by Drake, are typical examples of *pyri*, the specimens of *pyri* used in the original comparisons must have been mis-identified. The host and distribution given for *swainei* are within the limits of those known for *pyri*. The name *swainei* Drake, therefore, must be placed in synonymy under the older name *pyri* (Peck).

***Xyleborus saxeseni* (Ratzeburg)**

Bostrichus saxeseni Ratzeburg, 1837, Die Forst-Insekten 1: 167.
Xyleborus arbuti Hopkins (new synonymy), 1915, U.S. Dept. Agr. Rept. 99: 64.
Xyleborinus tsugae Swaine (new synonymy), 1934, Can. Ent. 66: 204.
Xyleborinus librocedri Swaine (new synonymy), 1934, Can. Ent. 66: 205.

The types of *tsugae* Swaine and *librocedri* Swaine and a specimen from Hopkins' original series of *arbuti* (sent to Swaine by Hopkins) were compared with several series of *saxeseni* from eastern, western, and southern parts of the United States and from Europe. Morphological differences were not apparent, the hosts were not unusual for this polyphagus species, and the distributions were continuous. Obviously only one species is represented.

***Xyleborus (Anisandrus) sayi* (Hopkins)**

Xyleborus obesus var. *minor* Swaine, nec. Stebbing, 1910, Can. Ent. 42: 164.
Anisandrus sayi Hopkins, 1915, U.S. Dept. Agr. Rept. 99: 68.
Xyleborus neardus Schedl (new synonymy), 1950, Ann. Mag. Nat. Hist., ser. 12, 3: 892.

The types of both *sayi* (Hopkins) and *minor* Swaine, and numerous other specimens bearing identification labels with these names, were examined; paratypes of *minor* were compared directly with the type of *sayi*. The distributions were continuous, and morphological differences were not apparent. Since host differences in polyphagus ambrosia beetles are insignificant, only one species is represented. Because *minor* Swaine is a junior homonym, the next oldest name, *sayi* Hopkins, must be used. The name *neardus* Schedl, used to replace the homonym *minor* Swaine, is automatically rejected.

***Xyleborus xylographus* (Say)**

Bostrichus xylographus Say, 1826, J. Acad. Nat. Sci. Philadelphia 5: 256.
Xyleborus canadensis Swaine (new synonymy), 1917, Dom. Canada Dept. Agr., Ent. Br. Tech. Bull. 14(1): 24.

Swaine's type series of *canadensis* consisted of four callow female specimens in rather poor condition. Examination of several thousand specimens of *Xyleborus* from eastern North America showed that his species is a synonym of *xylographus* (Say). In part, this conclusion was based on direct comparison of Swaine's holotype with a specimen of *xylographus* in the Canadian National Collection that had been examined by Say.

Studies of Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae)

III. Field Identification and some Notes on the Biology of *Neoleucopis pinicola* Mall. (Diptera: Chamaemyiidae)[1]

By R. C. Clark[2] and N. R. Brown[3]

Neoleucopis pinicola Mall. is a common predator on the pine bark aphid, *Pineus strobi* (Htg.) in New Brunswick. The host adelgid occurs throughout most of the United States and southern Canada on white pine, *Pinus strobus* L., Scots pine, *Pinus sylvestris* L., and Austrian pine, *Pinus nigra* Arnold (Craighead, 1950). It is also an occasional predator on the balsam woolly aphid, *Adelges piceae* (Ratz.) (Brown and Clark, 1956b). No reference to *N. pinicola* was found in the literature other than Malloch's (1921) description.

This paper is primarily concerned with distinguishing all stages of *N. pinicola* from a closely related introduced species, *N. obscura* (Hal.), using characters discernible in the field with a low power hand lens. It will supplement a previous paper (Brown and Clark, 1956a) where similar characters were given for three other chamaemyiids (*N. obscura*, *Leucopina americana* (Mall.), and *Cremifania nigrocellulata* Cz.). In addition, some notes on the seasonal life history, habits, and natural control are given. This information was obtained mainly from studies of *N. pinicola* as a predator of *P. strobi* in 1947, 1948, 1949, 1950, and 1956.

Adults were identified by personnel of the Insect Systematics and Biological Control Unit, Entomology Division, Ottawa. Photographic work was done by E. B. Bates, Forest Biology Laboratory, Fredericton.

Description for Field Identification

Egg (fresh material)	(Fig. 1)
Length	Av. 0.432 mm. Range 0.414-0.450 (8)
Width	Av. 0.166 mm. Range 0.144-0.180 (8)
Colour	White
Shape	Elongate oval, tapering more gradually at cephalic pole.
Surface	Has alternating brick-like pattern resulting from rectangular depressions between raised longitudinal and transverse lines.
Position	Usually attached to bark under "wool"; occasionally found loose among wool strands.

Larva, First Instar (preserved material)	(Fig. 2)
Length	0.576 mm. (1)
Width	0.180 mm. (1)
Colour	Creamy-yellow
Shape	
Body	Wedge-shaped
Anterior end	Gradually tapered from mid-section

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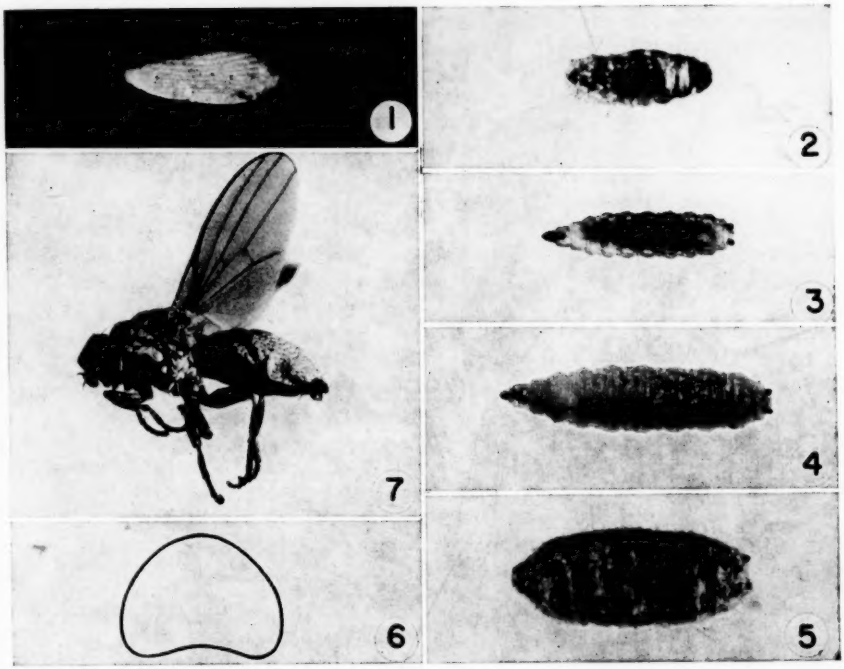

Figs. 1-7. *Neoleucopis pinicola*. 1, egg; 2, first-instar larva; 3, second-instar larva; 4, third-instar larva; 5, puparium; 6, cross-section of puparium; 7, adult.

Posterior end	Blunt
Dorsum	Slightly arched
Venter	Flat
General description for field identification	Indistinguishable in the field from *N. obscura*.
Larva, Second Instar (living material)	(Fig. 3)
Length	Av. 1.95 mm. Range 1.10-2.56 (8)
Width	Av. 0.46 mm. Range 0.29-0.73 (8)
Colour	Creamy-yellow
Shape	
Body	Wedge-shaped
Anterior end	Long gradual taper from mid-section
Posterior end	Weakly tapered, rounded apically
Dorsum	Somewhat arched
Venter	Flat
Segmentation	Indistinct
Texture of integument	Appears smooth
Covering	Mostly naked; sometimes has small amount of "wool" adhering, particularly towards posterior end.
Posterior respiratory processes	Very small, round

General description for field identification	Creamy-yellow; segmentation indistinct; posterior respiratory processes very small, inconspicuous; surface smooth, usually with very little covering of "wool".
Larva, Third Instar (living material)	(Fig. 4)
Length	Av. 2.66 mm. Range 2.19-3.28 (11)
Width	Av. 0.88 mm. Range 0.73-1.02 (11)
Colour	Dull yellow-grey, newly moulted larva yellowish.
Shape	
Body	Wedge-shaped
Anterior end	Gradually tapered from mid-section
Posterior end	Weakly tapered, blunt apically
Dorsum	Not strongly arched
Venter	Flat
Segmentation	Indistinct
Texture of integument	Granular
Covering	Dorsum usually has light covering of "wool".
Posterior respiratory processes	Much smaller and less conspicuous than in *N. obscura.*
General description for field identification	Dull yellow-grey; segmentation indistinct; posterior respiratory processes very small, not visible; granular appearance, with light covering of small pieces of "wool".
Puparium Detailed description	(Fig. 5)
Length	Av. 2.25 mm. Range 2.07-2.60 (16)
Width	Av. 0.90 mm. Range 0.83-1.04 (16)
Colour	Orange-brown when fresh, changing to yellow-brown or dark brown.
Shape	
From above	Oval, sides appearing almost parallel.
Cross section	Approximately semi-circular (Fig. 6)
Anterior end	Blunt, wedge-shaped, upper surface depressed and flattened.
Posterior end	Broadly rounded
Dorsum	Strongly arched
Venter	Slightly concave both transversely and longitudinally.
Segmentation	Fairly distinct, showing as dark lines on "wool" covered specimens.
Texture of integument	Roughened
Covering	Usually lightly covered with adelgid "wool".

Posterior respiratory processes	Inconspicuous, usually hidden by adhering "wool"; smaller than in *N. obscura.*
Position	Fastened to bark surface
General description of field identification	Orange-brown to dark brown; dorsum more strongly arched than in *N. obscura;* venter slightly concave longitudinally; usually lightly covered with "wool"; posterior respiratory processes small, not visible with naked eye, smaller than in *N. obscura;* segmentation generally distinct.
Adult	(Fig. 7)
General colour	Light blue-grey
Front of head	Blue-grey, square, with lighter margin laterally and ventrally.
Thorax	Light blue-grey
Halteres	Creamy-yellow colored, club round, not as conspicuous as in *N. obscura.*
Legs	Base to apex of tibia blue-grey, tibia slightly darker than femur; first two tarsal segments dark straw coloured, remaining segments darker.
Wings	Clear; no stigma
Abdomen	Light blue-grey; callow adults show extensive straw-coloured areas ventrally.

Biology

Seasonal Life History

Although sufficient records are not available for a detailed account of seasonal life history, our data imply that two generations occur per year, as in the closely-related *N. obscura.* These two generations are indicated on the accompanying chart (Fig. 8).

Overwintering stages are the second and third instar larvae and puparia. These complete their development the following spring. The adults begin to emerge soon after the first of June.

Eggs of the next, or summer, generation are laid during June and early July and development through the three larval instars occurs during June, July and early August. Puparia are formed about mid-July to mid-August. The first adults appear about July 20.

Eggs of the overwintering generation are laid in late July and part of August and larval development begins about the end of July. Second- and third-instar larvae and puparia hibernate and complete their development the following spring.

Habits

Two flight periods occur during the summer, the first from about mid-June to early July and the second from mid-July to the first part of August. During these periods the adults are found, sometimes in large numbers, flying about and crawling over adelgid-infested stems and branches. At this time the eggs are deposited, usually on the bark under adelgid "wool" and are firmly attached.

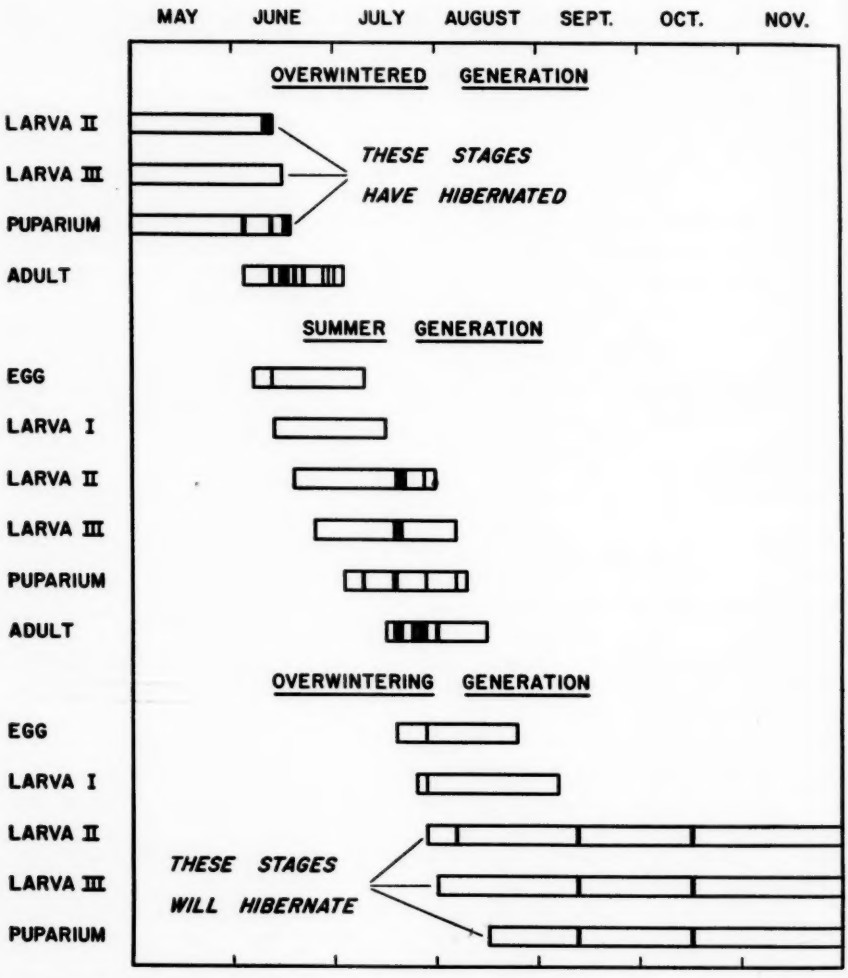

Fig. 8. *Neoleucopis pinicola.* Seasonal life cycle (vertical lines indicate dates of observation.

Occasionally eggs are found in the "wool" masses. Results of laboratory rearing of field-collected puparia indicate that the sex ratio is approximately 1:1.

The larvae feed on host eggs, immature stages, and adults, crawling through and under the "wool" masses in their search for prey. This leaves the "wool" in long strands loosely attached to the bark, when predation has been completed. No information is available regarding the number of prey consumed.

Biotic Control Factors

Two species of hymenopterous parasites have been recovered from *N. pinicola* — *Pachyneuron altiscutum* How. (Pteromalidae) and *Melanips iowensis* Ashm. (Figitidae). Only one specimen of the latter has been obtained, emerging in September from a puparium collected July 19, 1956. No reference to

this species, other than the original description (Ashmead, 1887. Amer. Ent. Soc. Trans. 14:158), has been found in the literature.

P. altiscutum is a common parasite on *N. pinicola*, as it is also on *N. obscura* and *Leucopina americana*. In 1948 collections of puparia were made on June 4 and July 8, representing both host generations. In 1956 a collection of summer generation puparia was made on July 19. No parasites emerged from the first collection and 89 per cent normal emergence of host adults occurred from these puparia. *P. altiscutum* emerged from 66.7 per cent of the summer generation puparia collected in 1948 and from 33.3 per cent in 1956. Sex ratios were 1:0.66 in 1948 and 1:1.43 in 1956.

These limited results suggest that *P. altiscutum* parasitizes only the summer host generation, or at least is a more important factor on this generation, and that the peak of the adult parasite's activity for the season occurs during the early part of July.

The only other insect so far found feeding on any stage of *N. pinicola* is a dermestid — *Perimegatoma* sp. Several larvae of this insect were found on *P. strobi*-infested trees on July 19 and August 6, 1956. One of these was observed feeding on a puparium of the chamaemyiid and had eaten a large hole through the dorsal surface and consumed most of the contents of the puparium. It is not known if this insect is predacious or saprophagous.

Control Value

No information is available on the control exerted on the host by this predator. As severe infestations of *P. strobi* are known to continue usually for several years on the same trees in the presence of the predator, it appears that, although the predator is very common, its feeding is not sufficient or is improperly timed to prevent host populations maintaining a fairly high level.

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Releases in North America and Reviews of Bionomics in Europe of Insect Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae)[1]

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The balsam woolly aphid, *Adelges piceae* (Ratz.), causes serious damage to balsam fir, *Abies balsamea* (L.) Mill., in Eastern Canada. It was introduced from Europe before 1900 (Balch, 1952) and has also become established in the northeastern United States. In continental Europe *A. piceae* is common on *Abies alba* Mill. but is not so serious a pest as in Canada. It has an extensive complex of insect predators in both Canada (Balch, 1934) and Europe (Delucchi, 1954). Balch (1934, 1952) found those in Canada inadequate as control agents. Some of the predators of *Pineus pini Koch* and *Pineus strobi* (Htg.) studied by Wilson (1938) in England, and recommended for introduction to new areas, were imported to Canada and released against *A. piceae*. Predators were first introduced from England in 1933 and later from continental Europe beginning in 1951.

Before 1951, six species were imported from England through the Farnham House Laboratory of the Imperial Institute of Entomology at Farnham Royal, England. These were released at many sites in Eastern Canada by officers of the Forest Biology Laboratory, Fredericton. The species were: *Aphidecta obliterata* (L.) and *Exochomus quadripustulatus* (L.) (Coleoptera: Coccinellidae), *Hemerobius nitidulus* F. and *Hemerobius stigma* Steph. (Neuroptera: Hemerobiidae), and *Neoleucopis obscura* (Hal.) and *Lipoleucopis praecox* de Meij. (Diptera: Chamaemyiidae). Since 1951, six species were imported from continental Europe through the Commonwealth Institute of Biological Control, Feldmeilen laboratory, Switzerland. These were released initially in one area near Fredericton, New Brunswick, by officers of the Belleville and Fredericton laboratories. The species were: *Aphidoletes thompsoni* Möhn (Diptera: Cecidomyiidae), *Cremifania nigrocellulata* Cz. (Diptera: Chamaemyiidae), *Laricobius erichsonii* Rosenh. (Coleoptera: Derodontidae), *Cnemodon* spp. (Diptera: Syrphidae), and *A. obliterata* and *Pullus impexus* (Muls.) (Coleoptera: Coccinellidae). This paper lists the species and numbers of predators released in North America and summarizes information on their life-histories and habits in Europe.

Methods of Introduction and Release

Precautions were taken in Europe during collection and packing to exclude parasites and disease organisms from the shipments. Before 1951, predators were sent to Canada by boat. A high mortality usually resulted because of the time involved. In 1951, special containers were designed (Delucchi, 1954) for air transport. On arrival at the Belleville laboratory, the shipments were immediately opened and inspected under quarantine conditions. Dead predators and undesirable insects were removed and a series of insects from each shipment was retained for permanent reference. The predators for release were transferred to metal, screen-sided cans, which were then sent by railway express to Eastern Canada in iced containers. The total time in transit from the field in Switzerland to the field in Canada was four days. Though some of the shipments contained weakened individuals, mortality in transit was negligible.

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Beginning in 1951, the first releases of all species were made in cages enclosing infested tree trunks, to ensure close association of the predators with their prey and to provide specimens for behaviour studies. These releases have been made in one area (Fredericton, New Brunswick) to facilitate studies of initial establishment and dispersal. After the initial establishment of a predator has been confirmed, and its behaviour studied, further releases have been made without using cages and with a barrier zone of at least 50 miles from the original release site.

Insect Releases

All predators were released as adults except *H. nitidulus* and *H. stigma*, the eggs of which were placed in the field. The species and numbers released, the release sites, and the years of releases are shown in Table I.

Aphidecta obliterata (L.)

According to H. G. Wylie (unpublished) of the Belleville laboratory, *A. obliterata* is widely distributed in northern and central continental Europe, where it is predacious on both *Adelges nüsslini* Börner and *A. piceae*. Though it has not been obtained in the British Isles from these species, it has been taken from other species of aphids. In England, Harrison (1913) noted its activity as a predator of *Cinara pinicola* (Kalt.) and Laidlaw (1936) reported it as the most important predator in the natural control of the Cooley spruce gall aphid, *Adelges cooleyi* (Gill.).

In Europe there appears to be one generation yearly. Van Dinther (1951) suggested the possibility of a second generation on some other species of aphids during the summer, but there is no direct evidence to support this. *A. obliterata* overwinters in the adult stage in sheltered situations of the forest floor. Low temperatures are probably important mortality factors. The eggs are deposited in the spring on either the needles or the trunks of fir trees. Because some eggs are laid on twigs, the larvae may attack the stages of *A. piceae* that cause the distortion of the growing tips in Canada. There are four larval instars, which feed on the spring generation of *Adelges*. The pupae are formed on the bark of the trees. Soon after emergence the adults leave the fir trees, and do not return until the following spring, when oviposition takes place. Wylie (unpublished) showed that under laboratory conditions the average oviposition period for 10 females of *A. obliterata* was 49 days. The oviposition rate was reduced when food became scarce. He stated that both the adults and the last-instar larvae attack all stages of *A. piceae* except the sessile first-instar larvae, or neosistens.

According to Delucchi (1953, 1955), two parasites attack *A. obliterata* in Europe. *Phalacrotophora berolinensis* Schmitz (Diptera: Phoridae) is a parasite of the pupae, and a roundworm of the genus *Hexamermis* (Nematoda: Mer-

TABLE I
Releases of Predators of *A. piceae* in Eastern Canada and United States (1933-1955)

Area of release	Year	Number
Aphidecta obliterata		
New Brunswick		
Fredericton, York Co.	1941	1,710
" " "	1951	271
" " "	1952	2,035
" " "	1955	51
Oak Bay, Charlotte Co.	1955	78
Rexton, Kent Co.	1955	67

Area of release	Year	Number
Aphidoletes thompsoni		
New Brunswick		
Fredericton, York Co.	1955	44
Cnemodon spp.		
New Brunswick		
Fredericton, York Co.	1954	703
Cremifania nigrocellulata		
New Brunswick		
Fredericton, York Co.	1952	676
" " "	1953	1,082
" " "	1954	3,318
" " "	1955	81
Exochomus quadripustulatus		
New Brunswick		
Millstream, Kings Co.	1935	95
Long Creek, Queens Co.	1935	110
Gagetown, Queens Co.	1936	1,300
Fredericton, York Co.	1936	1,450
" " "	1937	7,081
Burton, Sunbury Co.	1937	980
Fredericton, York Co.	1939	10,762
" " "	1940	1,593
Hemerobius nitidulus		
New Brunswick		
Millstream, Kings Co.	1935	110**
Hemerobius stigma		
New Brunswick		
Millstream, Kings Co.	1935	10**
Long Creek, Queens Co.	1935	220**
Fredericton, York Co.	1937	423**
" " "	1938	4,260**
Laricobius erichsonii		
New Brunswick		
Fredericton, York Co.	1951	2,177
" " "	1952	2,721
" " "	1953	9,122
Oak Bay, Charlotte Co.	1954	3,567
Rexton, Kent Co.	1954	2,131
Salisbury, Westmorland Co.	1954	2,081
Scotch Ridge, Charlotte Co.	1954	231
Tabusintac, Northumberland Co.	1954	595
Nova Scotia		
Earltown, Colchester Co.	1954	112
Harrison Settlement, Cumberland Co.	1955	870
Newfoundland*		
Robinson's Station	1952	843
Flat Bay Brook	1954	2,502
Harry's River, P.S.S. 15	1955	120
Jeffreys	1955	1,485
Little Barachois River	1955	1,399
Nardinis	1955	1,278
Pulpwood Siding	1955	892
St. Georges	1955	250
United States		
Searsburg, Vermont	1955	489
Woodstock, New Hampshire	1955	494

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Area of release	Year	Number
Lipoleucopis praecox		
New Brunswick		
Fredericton, York Co.	1933	3
Neoleucopis obscura		
New Brunswick		
Fredericton, York Co.	1933	2,253
" " "	1934	103
" " "	1936	30
New Maryland, York Co.	1936	468
Burton, Sunbury Co.	1936	436
French Lake, Sunbury Co.	1936	605
Geary, Sunbury Co.	1936	216
Jemseg, Queens Co.	1936	1,125
Nova Scotia		
Indian Gardens, Queens Co.	1941	533
Prince Edward Island		
Fortune Bridge, Kings Co.	1941	491
Red Point, Kings Co.	1947	104
Grand Tracadie, Queens Co.	1947	71
Brackley Point, Queens Co.	1947	120
Wellington, Prince Co.	1947	43
St. Nicholas, Prince Co.	1947	11
Newfoundland*		
Barachois River	1955	19
Nardinis	1955	2
United States		
Grantham, New Hampshire	1937	559
Pullus impexus		
New Brunswick		
Fredericton, York Co.	1951	3,572
" " "	1952	7,864
" " "	1953	11,663
Bass River, Kent Co.	1954	3,138
Moore Mills, Charlotte Co.	1954	1,883
Oak Bay, Charlotte Co.	1954	2,507
Petitcodiac, Westmorland Co.	1954	1,483
Rexton, Kent Co.	1954	2,063
Salisbury, Westmorland Co.	1954	2,109
Skiff Lake, York Co.	1954	2,494
Fredericton, York Co.	1955	50
Nova Scotia		
Riversdale, Colchester Co.	1952	2,139
McCallum Settlement, Colchester Co.	1955	120
Newfoundland*		
Robinson's Station	1952	1,306
" "	1953	1,534
Mouth of Humber River	1954	2,000
Nardinis	1954	2,570
White's Farm	1955	890
United States		
Searsburg, Vermont	1955	268

*Mouth of Humber River in Humber District, all other release areas in St. Georges District.
**Eggs.

mithidae) is a larval parasite. Van Dinther (1951) stated that the larvae and pupae of *A. obliterata* are attacked by the larvae of *Anatis ocellata* (L.) (Coleoptera: Coccinellidae), and Wylie observed the larvae of *E. quadripursulatus* attacking the pupae.

No progeny were recovered from the releases of this species up to 1952. The releases in 1941 were made on April 26 in two lots, one in an infestation of *A. piceae* and the other in an infestation of *Cryptococcus fagi* (Baer). Those in 1951 and 1952 were made on August 8 and on June 19 and 27 respectively. Releases in the spring of 1955 were made from May 9 to 27. In cage studies at Fredericton in 1955, eggs were deposited and the developing stages were observed feeding on *A. piceae*. It is not known whether these progeny survived the winter of 1955-56.

Aphidoletes thomsoni Möhn

The most important cecidomyiid predator of *A. piceae* in Europe is *A. thompsoni*, the adult and mature larva of which were described by Möhn (1954). Notes on the biology of this species have been taken from the work of Franz (1955) and Delucchi (1955).

A. thompsoni was obtained from all areas investigated in Germany and Switzerland. The known distribution extends from Flensberg, Germany, in the north to the Bavarian Alps and Zurich, Switzerland, in the south and as far west as Ribeauville, France. It preys on *A. piceae* and *A. nüsslini*, more commonly on *A. piceae*.

Adults of the first generation occur in May and those of the last generation in August. According to Franz (1955) there are three to five generations yearly and the duration of each is approximately four weeks. The females fly in swarms during the late afternoon and evening. The swarms occur 15-20 cm. from the bark of the infested firs. The adults apparently do not feed and their life span does not exceed five days. The eggs are laid in the wax masses of the prey and on the bark surface. The larvae feed on the eggs and both young and mature larvae of the prey. The mature larvae of *A. thompsoni* are able to propel themselves on a firm substratum, moving an average of 21 mm. according to Franz, the range being 4-45 mm. These observations were made at an air temperature of 25°C. Pupation occurs in the soil. Here each larva spins a silken cocoon, the outside of which is composed of soil granules. The mature larvae of the fall generation hibernate in the ground, but some of the immature larvae hibernate on the bark surface.

Up to 50 per cent of the larvae of *A. thompsoni* in the field are parasitized by *Aphanogmus compressus* (Ratz.) (Hymenoptera: Ceraphronidae). More than 35 per cent of the *A. thompsoni* larvae that were overwintered at the Belleville laboratory were parasitized by this species. Larvae of the cecidomyiid *Lestodiplosis* sp. were reported feeding on the developing stages of *A. thompsoni* by Möhn (1954).

Cremifania nigrocellulata Cz.

Delucchi and Pschorn-Walcher (1954) carried on intensive investigations on the life-history and habits of *C. nigrocellulata* in Switzerland. This species has been collected in Switzerland, Germany, and France and commonly preys on *A. piceae* throughout central Europe. It was not found preying on *A. nüsslini* at Ribeauville, France.

The life-history of *C. nigrocellulata* is well synchronized with that of *A. piceae* in Europe. There are three generations each year. The first preys on the spring generation of *A. piceae* and the second and third on the summer and autumn generations, respectively. There are three larval instars in each genera-

tion. Approximately 95 per cent of the puparia of the first generation remain in diapause on the bark of the fir trees during the summer, and approximately half of these continue in diapause throughout the following winter. The second-generation populations are low in relation to the first. The third-generation populations are the most abundant. The species over-winters in the puparial stage on the bark of *A. alba*.

The parasites reared from *C. nigrocellulata* in Europe include: *Lygocerus piceae* (Ratz.) (Hymenoptera: Ceraphronidae), a parasite of the third-instar larvae, and *Pachyneuron vitodurense* Del. and *Pachyneuron cremifaniae* Del. (Hymenoptera: Pteromalidae), parasites of the puparia.

Progeny from the releases have so far survived the winters. The adults dispersed rapidly after release and larvae have not been recovered in large numbers. As the habits of this species are somewhat similar to those of *N. obscura*, its dispersal may be as rapid as in that species. The native parasite *Pachyneuron altiscutum* How., which attacks both the introduced species *N. obscura* and the indigenous species *Leucopis americana* Mall. (Diptera: Chamaemyiidae) (Balch, 1952), will likely attack *C. nigrocellulata*.

Exochomus quadripustulatus (L.)

E. quadripustulatus feeds on both aphids and coccids, usually in heavy infestations. Wilson (1938) listed this species as a major predator of *Adelges* spp. on pine in the British Isles. He stated that it had been recorded from Europe and North and South America feeding on *Dacus oleae* (Gmel.) on olive, *Adelges* spp. on Scotch pine, five aphid and 16 coccid species on fruit trees, and *C. fagi* on beech; and Voukassovitch (1931) reported it as a predator of *Lecanium corni* Bouche in Yugoslavia. Near Ribeauville, France, Wylie (unpublished) found it on *A. nüsslini* but not on *A. piceae*. Delucchi (1954) considered it of very little significance in the control of *A. piceae* in Switzerland.

E. quadripustulatus overwinters mainly in the adult stage on the forest floor or in bark crevices on infested trees. Voukassovitch (1931) suggested that the larvae may also overwinter, as some were observed very early in the spring on *L. corni*. The eggs are deposited in the spring in bark crevices or among the wax of the prey, and oviposition continues from early spring to early summer (Wilson, 1938). Wylie (unpublished) showed that the larvae attack both adults and eggs of *A. nüsslini*. They pupate near the prey. Approximately 14 days are spent in the pupal period. Emergence of adults usually reaches a peak in midsummer and there is one generation each year. Adults collected during the summer did not deposit eggs in the laboratory.

No parasites of *E. quadripustulatus* were recorded by Wylie (unpublished) from field collections. The larvae of *E. quadripustulatus* were cannibalistic when prey species were not abundant. Pupae of *A. obliterata* were consumed on occasion by this species in the field.

The species has not been recovered from infestations of either *A. piceae* or *C. fagi*.

Hemerobius stigma Steph. and *H. nitidulus* F.

In the British Isles, Laidlaw (1936) reported *H. stigma* from Douglas fir, larch, Scotch pine, and spruce in association with *Adelges cooleyi* (Gill.), *A. viridis* Ratz., *Cinara pini* (L.), and *Rhapalosiphum abietina* (Wlk.) respectively. Wilson (1938) indicated that it was one of the most common predators in England on firs and second in importance only to *N. obscura*. It has not been recorded as an important predator of *A. piceae* in central Europe.

There are two generations annually in Scotland (Laidlaw, 1936) and probably three in the south of England (Wilson, 1938). This species passes the

coldest part of the winter in the prepupal stage. The eggs are laid on the needles in the spring and hatch in approximately 14 days. According to Laidlaw (1936), the early-instar larvae are unable to puncture either the cuticle of mature larvae of *Adelges* spp. or the chorion of the egg. Their food therefore consists mainly of newly hatched larvae. The larva matures in approximately 30 days. There are three larval instars. The adults attack all stages of the prey but prefer the eggs.

H. nitidulus is usually found in association with *H. stigma* but is never as common (Wilson, 1938). The habits of the two species are similar and the immature stages of the two species are difficult to distinguish from each other.

Wilson (1938) reared two parasites from the mature larvae of *H. stigma*: *Anacharis ensifera* Walk. and *A. eucharoides* (Dalm.) (Hymenoptera: Figitidae).

Neither of these species was recovered. However, Balch (1952) found three indigenous species of hemerobiids attacking *A. piceae* in New Brunswick. One of these was *Hemerobius stigmaterus* Fitch (Neuroptera: Hemerobiidae).

***Laricobius erichsonii* Rosenh.**

Brown (1944) stated that this European species, which had been confused with the indigenous species *rubidus* Leconte, may be distinguished by the size of the punctures of the head and by characters of the male genitalia.

Franz (1953) reported on the life-history and habits of this species in Europe as follows. It is a predator of *Adelges* spp. on firs and occurs from the Italian Alps to southern Denmark, from Normandy to the Carpathian Mountains, and from sea level to altitudes of 2,000 meters. It is restricted to areas with an annual precipitation of at least 600 mm. Though *L. erichsonii* has been recorded preying on *A. nüsslini* on fir, *A. cooleyi* on Douglas fir, *Pineus pineoides* Chol. on spruce, *Pineus strobi* (Htg.) on pine, and other species of *Adelges*, its preferred prey is *A. piceae*.

The adults live for approximately one year. They overwinter in the soil, from which they emerge in the spring in response to higher temperatures. The adults resume feeding, and mate and oviposit on the fir trees infested with the prey. The adults attack all the stages of *A. piceae* except the first-instar larvae. Each female lays approximately 50 eggs, singly in the wax of the prey. There are four larval instars. All larvae puncture the eggs and adults of the prey and ingest their contents. They secrete an adhesive substance to which the white wax covering of the adelgids adheres. When the prey is very scarce, the last-instar larvae do not produce this secretion. When feeding is complete the fourth-instar larvae move to the forest floor, where they pupate after approximately nine days. The pupal period lasts approximately two weeks. The newly emerged beetles appear on the trees in early summer and feed before entering the soil to overwinter. They are not so active as the spring adults and their ovaries remain undeveloped until the following spring.

Inadequate moisture content of the soil is an important cause of mortality among the pupae. The adults appear to locate their food readily and can survive on many species of prey. The larvae, however, are not able to detect or locate food more than a few centimetres distant. Mortality among the larvae is high when there is increased competition for food because of the presence of other predators, and when the prey is scarce. The larvae of *P. impexus* occur one to two weeks earlier and may reduce the density of the prey to such an extent that *L. erichsonii* is adversely affected.

The most important predators of the larvae of *L. erichsonii* are *Syrphus arcuatus* (Fall.) (Diptera: Syrphidae), *Anatis ocellata* L., *A. obliterata*, and *Chrysopa ventralis* Curt. (Neuroptera: Chrysopidae), and *Lygus atomarius* Mey.

(Hemiptera: Miridae). The eggs are eaten by *P. impexus* and by slugs of *Limax*, *Arion*, and other genera.

One species of parasite, *Echthrolaricobius paradoxus* Perkins (Hymenoptera: Ichneumonidae), attacks the larvae of *L. erichsonii*. This parasite is found throughout the range of *L. erichsonii* in Europe. The parasite oviposits in the third- and fourth-instar larvae of the host on the trees. The parasites emerge the following year when third- and fourth-instar larvae of *L. erichsonii* are present. In Europe the larvae of *L. erichsonii* are attacked by an unidentified disease, the importance of which has not yet been ascertained.

L. erichsonii is well established in the Fredericton area, where it has completed four generations since its initial release in 1951. Field studies by the senior author show that the life-history of this species in Canada is similar to that in Europe.

Neoleucopis obscura (Hal.)

N. obscura is the most important predator of *Pineus pini* Koch and *P. strobi* in England (Wilson, 1938). It is found in smaller numbers on the larch aphid. Delucchi (1954) considered *N. obscura* to be among the specialized predators that attack Adelginae in central Europe. This species plays an important part in the destruction of *A. piceae*, but is not one of the most active predators. Wylie (unpublished) found *N. obscura* particularly abundant in infestations of *A. nüsslini* at Ribeauville. According to Balch (1952) the predator is also known from Sweden and has become established in the Maritime Provinces of Canada.

In England, Wilson (1938) recorded two annual generations. Wylie indicated that two generations were known to occur in France. *N. obscura* overwinters in the larval stage in England, whereas in Switzerland both larvae and puparia apparently hibernate (Delucchi, 1954). Adults emerge in the spring. Eggs are usually deposited singly in the wax of the adelgids and the larvae feed beneath the wax. The larvae pass through three instars. Wylie (unpublished) stated that the spring generation was the most numerous in France, whereas Delucchi (1954) stated that the autumn generation was most numerous in Switzerland. The larvae feed on eggs, larvae, and adults of *Pineus* spp. in England (Wilson, 1938). In France, according to Wylie (unpublished) the predator was not observed feeding on the eggs of either *A. piceae* or *A. nüsslini*.

Wilson (1938) reared three species of parasites from puparia of *N. obscura* in England: *Lygocerus testaceimanus* Kieff. (Hymenoptera: Ceraphronidae), *Melanips longitarsus* (Reinh.) (Hymenoptera: *Figitidae*), and *Aphidencyrtus aphidivorus* (Mayr) (Hymenoptera: Encyrtidae). In Europe, Delucchi (1954) reared *Lygocerus piceae* (Ratz.) (Hymenoptera: Ceraphronidae) and *Pachyneuron vitodurense* Del. (Hymenoptera: Pteromalidae) from the mature larvae and pupae, respectively. Wylie (unpublished) found that the larvae of *N. obscura* are attacked by larvae of *Chrysopa ventralis*, *A. ocellata*, and *A. obliterata*. Cannibalism among larvae of *N. obscura* was observed in the laboratory during periods of food scarcity. In Canada, *N. obscura* is attacked by the native parasite *P. altiscutum* (Balch, 1952).

The establishment in Canada of this predator from the releases of 1933 to 1936 was described by Balch (1952). Though *N. obscura* has become established in most of the areas infested by *A. piceae* in Eastern Canada, it has not provided adequate control. One of the reasons for failure is the limited searching capacity of the larvae on lightly infested trees (Balch, 1952).

Lipoleucopis praecox de Meij.

L. praecox occurs regularly but is not numerous in infestations of *Pineus pini* in England (Wilson, 1938). *P. pini* is perhaps its only prey.

There is one generation annually. The adults emerge and eggs are laid in the early spring, on the twigs of the host plant. The larvae are found singly under shelters on one-year-old twigs, usually at the bases of the needles or lower on the stem. The shelters are formed of bud scales and the wax of *P. pini*. Within each shelter are found three to six females of *P. pini* and one larva of *L. praecox*. During its development the *L. praecox* larva feeds on the eggs and nymphs and does not attack the adult females until just before pupating. The larva pupates and the puparium overwinters within the shelter.

Wilson (1948) took two parasites from the overwintering puparia of *L. praecox*: *Cerchysius subplanus* (Dalm.) (Hymenoptera: Encyrtidae) and *Pachyneuron* sp. (Hymenoptera: Pteromalidae).

The three adults released at Fredericton, New Brunswick, in 1933 did not constitute an adequate release. As this predator appears so specialized for *P. pini* in England it is doubtful that it could adapt itself to *A. piceae* in Canada unless establishment were possible on the stages of *A. piceae* that cause distortion of the growing tips.

Cnemodon spp.

The generic name *Cnemodon* is used to include the syrphid predators of *A. piceae* sent to Canada as *Cnemodon latitarsis* Egg. The taxonomy of the *Cnemodon* complex in Europe has been studied by Delucchi and Pschorn-Walcher (1955). Very little is known of the life-history and habits of the species studied other than that some are associated with *A. piceae*.

Delucchi (1954) recorded *Diplazon collinus* Stelfox (Hymenoptera: Ichneumonidae) as a parasite.

No progeny of those released have been observed and it is improbable that the species became established.

Pullus impexus (Muls.)

P. impexus is found from central Europe to North Africa. It appears to occur farther south than *A. piceae* and probably preys on different species of aphids in the southern part of its range. In Europe, *P. impexus* prefers *A. piceae*.

The life-cycle of *P. impexus* is well synchronized with that of *A. piceae* in Europe. Delucchi (1954) conducted intensive studies on the life-history and habits of this predator in Switzerland. It overwinters in both the egg and adult stages. The eggs hatch in the spring and the four larval instars feed on the spring generation of *A. piceae*. The larvae pupate on the bark of the infested fir trees. The ovaries of the adult females are undeveloped on emergence and require approximately one month in which to mature. The females are relatively inactive during this period. They mate and oviposit after this period of inactivity. Oviposition is practically confined to the autumn, the spring oviposition being of negligible importance from a control point of view. With the onset of lower temperatures in the late autumn the adults hibernate in bark crevices on the fir trees. Mating and oviposition continue during the next spring. Though the adults that overwinter coexist with adults from the spring generation it is improbable that they interbreed with them. The eggs of the overwintered adults are not known to hatch in the same year, and probably attain the same embryonic development as those eggs laid in the autumn.

The biotic factors, other than availability of *A. piceae*, that tend to reduce the population of *P. impexus* in Europe consist primarily of parasites and predators. Delucchi (loc. cit.) cited an instance in which, in the absence of its parasites and with a small number of its predators present, up to 30 larvae of *P. impexus* per square decimeter were found in an infestation of *A. piceae* of high density. As a result *P. impexus* almost completely destroyed the infestation of

A. piceae. The European parasites of *P. impexus* include *Scymnophagus mesnili* Del. (Hymenoptera: Pteromalidae), a parasite of the pupae; *Centistes scymni* Ferrière (Braconidae: Leiophroninae), a parasite of the adult females; Sporozoa belonging to the Gregarinida, parasites of the adult females; and a nematode (Mermithidae), a parasite of the adult females. *C. scymni* is the most effective parasite. Other parasites are probably of minor importance. The predators of *P. impexus* include the mature larvae of *C. ventralis*, *Cnemodon* spp., and *S. arcuatus;* and the bird *Certhia familiaris* L., the brown creeper.

In the Fredericton area this species has been recovered for four consecutive years beginning in 1952. The life-history in Canada is generally similar to that in Europe. In Canada the larvae of both *A. piceae* and *P. impexus* develop later in the spring than in Europe. The aestivosistens generation of *A. piceae* and the oviposition period of *P. impexus* occur earlier in Canada than in Europe. These differences are probably caused by differences in climate.

Summary

From 1933 to 1955, 11 species of insect predators of *A. piceae* were introduced from Europe into Eastern Canada. The areas and years of releases and the numbers released are given for each of the species, and their life-histories, habits, and natural enemies in Europe are reviewed. Of the six species from England, only *Neoleucopis obscura* has become established over most of the area infested by *A. piceae* in New Brunswick, Nova Scotia, and Prince Edward Island. Three of the six species from Switzerland and Germany are established in the Fredericton, New Brunswick, area: *Cremifania nigrocellulata*, *Laricobius erichsonii*, and *Pullus impexus*.

Acknowledgments

The authors are grateful for the co-operation from the officers of the Forest Biology Laboratory, Fredericton, New Brunswick, and are particularly indebted to Dr. H. G. Wylie, of the Belleville laboratory, for permission to use data from unpublished manuscripts.

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Two new species of *Mulcticola* (Philopteridae: Mallophaga).

By K. C. Emerson, Stillwater, Okla. and Robert E. Elbel, Lawrence, Kan.

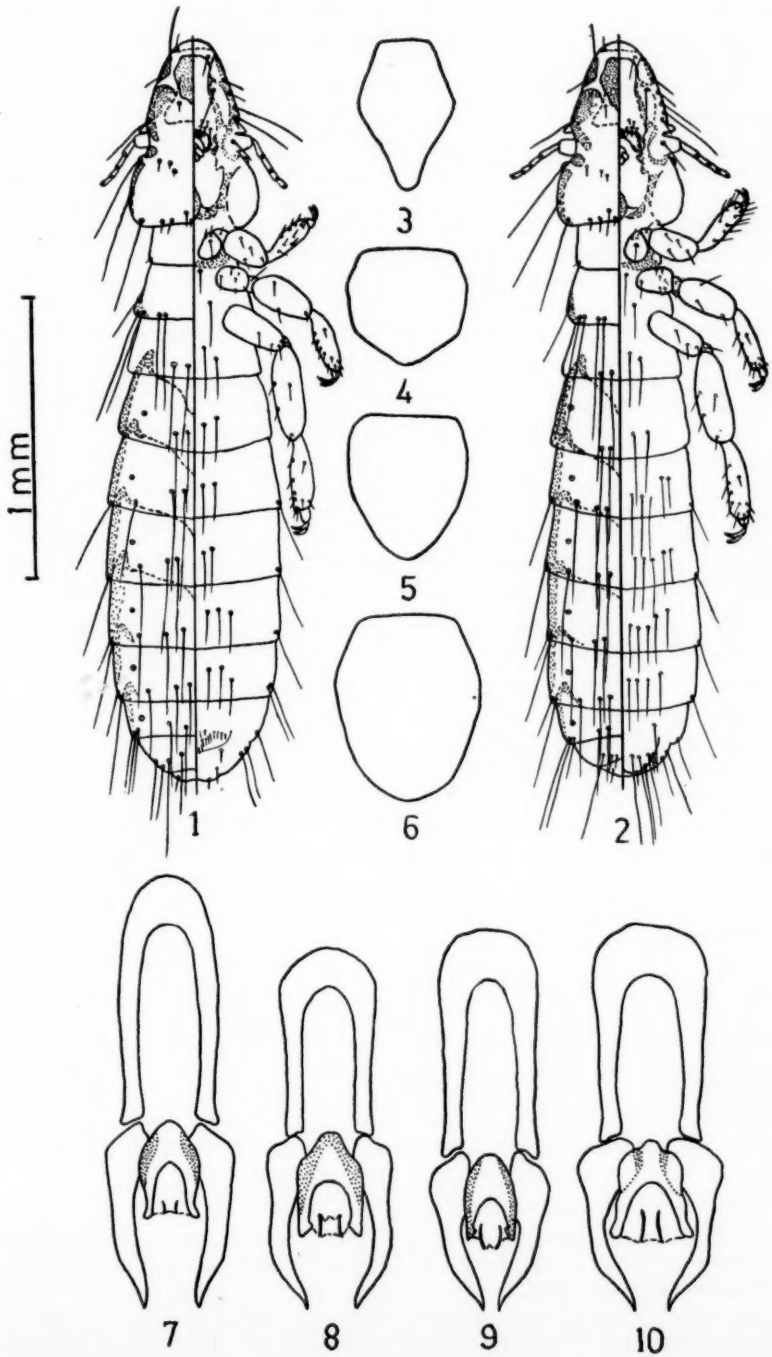
The Ischnoceran genus *Mulcticola* Clay and Meinertzhagen, 1938, contains five forms found on the avian family Caprimulgidae. The known species, and type host, are: *M. hypoleucus* (Denny), 1842, found on *Caprimulgus europaeus europaeus* Linnaeus; *M. macrocephalus* (Kellogg), 1896, found on *Chordeiles minor henryi* Cassin; *M. nacunda nacunda* Carriker, 1945, found on *Podager nacunda minor* Cory; *M. nacunda peruviana* Carriker, 1945, type host is unknown (presumed to be a member of the Caprimulgidae); and *M. tenuiceps* Carriker, 1945, found on *Podager nacunda nacunda* (Vieillot). A new species is described from material collected by one of the authors while assigned to the United States Operations Mission to Thailand. The other new species is described from material in the British Museum (Natural History), which was graciously loaned by Dr. Theresa Clay. Appreciation is also expressed to the United States National Museum and to the Snow Entomological Museum of Kansas University for the loan of specimens.

External morphological differences between the species are not great, indicating an exceptionally compact genus. Specific characters which appear to be of taxonomic value are: size, shape of the dorsal anterior plate of the forehead, male genitalia, and chaetotaxy of the female genital region. Carriker has illustrated the male genitalia and dorsal anterior plate of the forehead of the three forms he described; in addition, a table of measurements is given for each. For the other species of the genus, illustrations of the dorsal anterior plate of the forehead and male genitalia have been included in this paper. A comparison of these structures apparently offers the best means for separation of the species.

Mulcticola deignani n. sp.

Male: As illustrated in figure 2. Dorsal anterior plate of forehead as illustrated in figure 3. Genitalia as illustrated in figure 10.

Figures 1 and 2. *Mulcticola deignani* n. sp., drawn to the same scale.
Fig. 1. Dorsal-ventral view of female.
Fig. 2. Dorsal-ventral view of male.
Figures 3-6. *Mulcticola* species, dorsal anterior plate of forehead; drawn to the same scale.
Fig. 3. *M. deignani* n. sp.
Fig. 4. *M. macrocephalus* (Kellogg), 1896.
Fig. 5. *M. minutus* n. sp.
Fig. 6. *M. hypoleucus* (Denny), 1842.
Figures 7-10. *Mulcticola* species, male genitalia; drawn to the same scale.
Fig. 7. *M. minutus* n. sp.
Fig. 8. *M. hypoleucus* (Denny), 1842.
Fig. 9. *M. macrocephalus* (Kellogg), 1896.
Fig. 10. *M. deignani* n. sp.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Female: As illustrated in figure 1. Posterior margin of vulva broadly rounded; armed with approximately twenty-eight medium-length setae arranged in two irregular rows, and eight short setae.

This is the only known species in which the chaetotaxy of the male abdominal segments IV-VII differs from that of the female. Other differences are apparent from a comparison of figures 3-10.

Type host: *Caprimulgus macrurus bimaculatus* Peale.

Type material: Holotype male and allotype female collected at Lopburi, Thailand by Robert E. Elbel on 20 July 1953, have been deposited in the United States National Museum. Paratypes include: four males and three females collected on Nip Mountain, Lopburi, Thailand by Robert E. Elbel on 20 July 1953; four males and two females collected on Lomlo Mountain, Ban Maeo, Koksathon, Dansai, Loei, Thailand by Robert E. Elbel and Boonsong Lekagul on 28 March 1954; two females collected at Hinlaem, Trakhanum, Kanachanaburi, Thailand by Robert E. Elbel and H. G. Deignan on 23 November 1952; six males and one female collected at Khlong Khlung, Kanphaeng Phet, Thailand by Robert E. Elbel and H. G. Deignan on 24 April 1953; seven males and eleven females collected on Lomlo Mountain, Koksathon, Dansai, Loei, Thailand by Robert E. Elbel on 27 and 28 February, 1955; and three males and two females collected on Phak Khi Nak Mountain, Koksathon, Dansai, Loei, Thailand by Robert E. Elbel on 19 March 1955, all found on the type host. Three males and three females collected in Nepal on *Caprimulgus macrurus albonotatus* Tickell during October, 1935 are in the British Museum (Natural History.)

This species is named for Mr. H. G. Deignan, United States National Museum, in appreciation for the Mallophaga he collected while in Thailand.

***Mulcticola minutus* n. sp.**

Male: Similar to *M. deignani* in general form. Dorsal anterior plate of forehead as illustrated in figure 5. Tergites II-VII each with four long median setae; sternites III-VII each with five long setae, remainder of chaetotaxy as in *M. deignani*. Genitalia as illustrated in figure 7.

Female: Similar to male in general form. Chaetotaxy, except for terminal abdominal segments, same as in the male. Vulva broadly rounded, armed with approximately twenty-eight medium-length setae arranged in a row on the margin, and with twenty-four scattered short setae.

Measurements:

	Male		Female	
	Length	Breadth	Length	Breadth
Head	0.67 mm	0.52 mm	0.70 mm	0.56 mm
Prothorax	0.20	0.37	0.22	0.39
Pterothorax	0.21	0.52	0.22	0.53
Abdomen	1.63	0.68	1.77	0.75
Total	2.70		2.86	

This species is closest to *M. deignani*. In addition to differences in chaetotaxy, the two may be separated by a comparison of figures 3-10.

Type host: *Caprimulgus asiaticus asiaticus* Latham.

Type material: Holotype male, allotype female, six paratype females, and three paratype males in the British Museum (Natural History) were collected in Deccan during February 1937.

The illustrations of *M. hypoleucus* (Denny), 1842, are from specimens in the British Museum (Natural History) collected off *Caprimulgus europaeus*

europaeus Linnaeus at Suffolk, England, during August 1935. The illustrations of *M. macrocephalus* (Kellogg), 1896 are from specimens in the United States National Museum, collected off *Chordeiles minor minor* (J. R. Forster) at Charleston, South Carolina on 7 September 1931 by H. S. Peters.

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Effects of Temperature and Humidity on Toxicities of Three Insecticides to Larvae of the Codling Moth (Lepidoptera: Olethreutidae)[1]

By M. D. Proverbs[2]

Before the advent of synthetic organic insecticides, it was much more difficult to control the codling moth, *Carpocapsa pomonella* (L.), in arid, hot areas with a long growing season, as in the Pacific northwest, than in cooler areas such as Ontario, where there is more rainfall and usually a shorter growing season. As a rule, in all apple growing areas, the codling moth is most numerous during summers in which the temperatures are above normal, particularly if the prevailing temperatures are high at dusk, when the moth is ovipositing. Consequently, unsatisfactory control in hot, dry areas, such as the South Okanagan of British Columbia, was attributed largely to the direct and favorable influence of climate on codling moth development (Webster, 1936).

When DDT and methoxychlor were introduced throughout Canada for the control of the codling moth, entomologists in British Columbia obtained as good and sometimes evidently better control than entomologists in Ontario. Was some climatic factor in British Columbia so favorable for the use of these synthetic organic insecticides that exceptionally good control of the codling moth was obtained even though the climate was very favorable for the development of the insect? And was the climate of British Columbia unfavorable for the use of the older insecticides such as lead arsenate?

Experiments were conducted from 1951 to 1953 at the Summerland laboratory to determine the effects of relative humidity and temperature on the toxicities of lead arsenate, DDT, and methoxychlor to codling moth larvae. Larvae were exposed to sprayed and non-sprayed apples held at various humidity-temperature combinations. The possible influence of relative humidity, rainfall, and temperature on the control of codling moth larvae in British Columbia and Ontario is discussed on the basis of the observed larval mortalities.

Materials and Methods

Rearing

Codling moth larvae were collected by banding apple trees or by collecting infested fruits. Moths that developed from these larvae were placed in oviposition cages. Each cage was cylindrical, of wire-screen, nine inches tall and

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seven inches in diameter. The floor was of plywood, covered on its upper surface with a sheet of wax paper; the lid was of cloth or wire screen. A pad of wet absorbent cotton was placed on the floor to provide water for the moths. The cages were kept in the laboratory at room temperature. The moths readily oviposited on the wax paper when 100 to 150 of them were crowded into each cage. Every day the wax paper was renewed. The papers bearing the eggs were kept at approximately 65°F. and 60 per cent relative humidity until the eggs reached the black-head stage, that is, until the blackish head capsule of the developing larvae could be distinctly seen through the chorion.

Testing

The stem and calyx depressions of immature McIntosh or Delicious apples were filled with hot paraffin wax. Each apple was suspended from a stand by a cotton thread attached to the stem, and sprayed individually with a suspension of the insecticide in distilled water. The insecticides used were in wettable powder formulations: (1) 50 per cent DDT from Pennsylvania Salt Manufacturing Company, Tacoma, Wash., (2) 50 per cent methoxychlor from Canadian Industries Limited, Montreal, Que., and (3) 96 per cent lead arsenate, also from Canadian Industries Limited. The insecticides were applied with a Vibro-Sprayer, Model No. VS-600, Burgess Vibrocrafters, Incorporated, Chicago, Ill., or a paint gun, Model No. P21B (18) A1E, American Brake Shoe Company, Kellog Division, Rochester, N.Y. The apples were given an initial rotation by rolling the stem between the thumb and forefinger immediately before spraying. In this way a uniform spray coverage was obtained. Spraying was discontinued just before drip commenced. The sprayed apples were then suspended by the cotton threads from nails driven into strips of wood, usually ten apples to each strip. While the apples were drying, small squares or rectangles, each bearing one egg in the black-head stage, were cut out of the wax paper on which the moths had oviposited. As soon as the apples were dry, one of the paper sections was pinned with a minuten nadel to the wax at the stem end of each apple. The wooden strips bearing the apples were then transferred to cabinets, where the temperature was controlled within $\pm$ 0.5 degrees Fahrenheit and the relative humidity within ± 2 per cent. Apples in the controls were not sprayed; otherwise they were handled similarly to sprayed apples. Larval entries were recorded approximately two weeks after the apples were introduced into the cabinets.

In two of the experiments, some of the sprayed and non-sprayed apples were suspended from the wooden strips and exposed to the weather under a peach tree in the laboratory orchard. One week later the apples were artificially infested with the codling moth as already described.

As a rule, each experiment was replicated ten or 15 times, with ten apples per replicate.

Results and Discussion

The number of codling moth larvae that entered non-sprayed fruit was not significantly greater at high than at low temperatures (Tables I to V). Differences might have resulted if the larvae had been exposed to a wider range of temperatures.

When apples were sprayed with three grams of 96 per cent lead arsenate per litre of water, the percentages of codling moth larvae that survived at the following temperature-humidity combinations were:—

Temperature and humidity	Lead arsenate	Check
86°F., 60% R.H.	39	88
86°F., 95% R.H.	32	90
70°F., 95% R.H.	26	82

There was no significant difference at the five per cent level for either lead arsenate or the check.

In a second experiment, in which other temperature-humidity combinations were used, it was again found that temperature and humidity had no measurable effect on the immediate toxicity of lead arsenate (Table I).

TABLE I

Percentages of apples with live codling moth larvae at several combinations of temperature and humidity after spraying with certain amounts of wettable powders of three insecticides per litre of water.

Temperature and humidity	DDT, 50% 0.08 gm.	Methoxychlor, 50% 0.08 gm.	Lead arsenate, 96% 3.0 gm.	Check
75°F., 50% R.H.	14	23	28	86
90°F., 50% R.H.	27	55	31	87
75°F., 100% R.H.	35	49	31	88
90°F., 100% R.H.	43	70	26	92
Difference required for significance at 5% level	7	11	2	2

Cutright (1931) and Hough (1934) reported that when apples were sprayed with lead arsenate the number of codling moth entries varied directly with temperature. However, the published results are not sufficiently detailed to tell whether temperature influenced the toxicity of the lead arsenate. The difference in numbers of larval entries might have resulted from the direct influence of temperature on the larva itself.

Steiner and Arnold (1943) showed that, under certain conditions, temperature and humidity may have an immediate effect on the toxicity of lead arsenate to codling moth larvae. They experimented with spray mixtures of lead arsenate, copper sulphate, and lime. Where lead arsenate was used at three pounds per 100 United States gallons of spray (equivalent to approximately 3.6 grams per litre), they found that changes in temperature and relative humidity had no measurable influence on toxicity. However, when the concentrations of the materials were increased and the lead arsenate was used at four pounds per 100 gallons, the toxicity of the mixture immediately decreased at the higher temperatures and the lower humidities. From this they inferred that poor control of the codling moth with lead arsenate in the Pacific northwest is partly due to the hot, dry climate that prevails in much of that region.

The South Okanagan Valley of British Columbia is hot and semi-arid, but limited hygrograph records made in the irrigated orchards of the Okanagan Valley indicated that the averages of the maximum, minimum, and mean relative humidities in the orchards during summer are much higher than are commonly realized, and are sometimes four to nine per cent higher than in apple-growing areas in Ontario. Consequently, as far as humidity is concerned, Steiner and Arnold's explanation does not evidently hold true for the South Okanagan.

Temperature records from apple orchards in the Okanagan Valley showed that the averages of the maximum and mean temperatures during the months of codling moth activity are very similar to those in apple-growing areas in Ontario. The averages of the minimum temperatures in Ontario orchards are lower than those in the Okanagan, but the differences (three to six degrees Fahrenheit) do not appear sufficiently great to have the marked influence on the toxicity of lead arsenate suggested by Steiner and Arnold.

TABLE II

Percentages of apples with live codling moth larvae at two combinations of temperature and humidity after spraying with 0.1 gm. of 50% DDT wettable powder per litre of water and weathering one week in an orchard.

Temperature and humidity	DDT		Check	
	Weathered	Not weathered	Weathered	Not weathered
88°F., 95% R.H.	34	20	86	86
88°F., 70% R.H.	46	28	90	86

Tables I to III indicate that the toxicity of DDT to codling moth larvae was not appreciably influenced by humidity, provided the air was not saturated with water vapor. This was true whether or not the DDT deposits had been previously weathered. Evidently then, with DDT, differences in humidity between the orchards of British Columbia and Ontario are probably not responsible for the occasional differences in control of codling moth larvae.

Significantly more larvae entered DDT-sprayed apples held at 100 per cent relative humidity than at any other level of humidity that was examined (Tables I and III). During summer, the rainfall in the apple-growing areas of Ontario is two to four times that in the Okanagan Valley. One would therefore expect DDT to give better control of the codling moth in the Okanagan Valley than in Ontario. However, from June to September, the number of days with rain is approximately the same in the two areas. In other words, the DDT deposits on apple trees in Ontario probably do not remain wet very much longer than those in the Okanagan. Consequently, with DDT, the difference in codling moth control between the two areas, as a result of differences in rainfall, is probably not so great as would at first appear.

High temperatures caused an immediate reduction in the toxicity of DDT to the larvae, whether or not the deposits had been previously weathered (Tables I and IV). As was noted earlier, the maximum and mean temperatures during summer are approximately the same in the orchards of Ontario and British Columbia, whereas the minimum temperatures are somewhat lower in Ontario. The lower minimum temperatures in Ontario would tend to give better control in that area. However, there is a difference of only a few degrees in average

TABLE III

Percentages of apples with live codling moth larvae at 75°F. and four humidities after spraying with 0.02 gm. of 50% DDT wettable powder per litre of water.

Relative humidity %	DDT	Check
45	26	89
60	28	93
90	20	91
100	47	92
Difference required for significance at 5% level	15	—

TABLE IV

Percentages of apples with live codling moth larvae at two combinations of temperature and humidity after spraying with 0.1 gm. of 50% DDT wettable powder per litre of water and weathering one week in an orchard.

Temperature and humidity	DDT		Check	
	Weathered	Not weathered	Weathered	Not weathered
88°F., 95% R.H.	66	40	71	77
70°F., 95% R.H.	23	9	74	73
Difference required for significance at 5% level	20	15	—	—

minimum temperatures between the two areas, probably not enough to cause measurable differences in control.

The effects of temperature and humidity on the immediate toxicity of methoxychlor to codling moth larvae were the same as for DDT (Tables I and V). That part of the discussion pertaining to DDT therefore can be applied equally well to methoxychlor.

It may be concluded that, with DDT or methoxychlor, summer temperatures in British Columbia apple orchards are less favorable than those in Ontario orchards for initial control of codling moth larvae, whereas rainfall is more favorable. However, these factors are probably of minor importance. Evidently, with lead arsenate, differences in temperature and rainfall between these apple-growing areas have no influence on the initial control of the larvae. With DDT, methoxychlor, or lead arsenate, differences in humidity between the two areas probably have no measurable effect on the initial control.

Summary

At constant temperature, the toxicities of DDT and methoxychlor to larvae of the codling moth, *Carpocapsa pomonella* (L.), were not markedly influenced by changes in relative humidity, provided the air was not saturated with water vapor. At 100 per cent relative humidity, the toxicities were much lower than at any other humidity investigated. At constant relative humidity, DDT and methoxychlor were each more toxic at low than at high temperatures. Differences in temperature or humidity had no measurable effect on the toxicity of lead arsenate. With DDT or methoxychlor, summer temperatures in British

TABLE V

Percentages of apples with live codling moth larvae at three combinations of temperature and humidity after spraying with 0.08 gm. of 50% methoxychlor wettable powder per litre of water.

Temperature and humidity	Methoxychlor	Check
86°F., 95% R.H.	28	84
86°F., 60% R.H.	35	84
70°F., 95% R.H.	12	81
Difference required for significance at 5% level	11	—

Columbia orchards are less favorable than those in Ontario for initial control of codling moth larvae, whereas rainfall is more favorable. With lead arsenate, differences in temperature and rainfall, and with DDT, methoxychlor, and lead arsenate, differences in humidity between the two apple-growing areas evidently have no measurable effect on initial control.

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On the Identity of the Gunthorp Types, Part II,[1] and Some Notes on Plectrotaxic Criteria (Chilopoda: Lithobiomorpha: Lithobiidae)

Ralph E. Crabill, Jr. and Michael A. Lorenzo, S.J.[2]

In 1913 Horace Gunthorp described a new Kansan lithobiid, *Lithobius kansensis* (4, p. 166), which he compared with what he took to be a closely related species, *cantabrigensis* Meinert (5, p. 177). Although the new species was inadequately characterized, it is still possible to say that it is undoubtedly referrable to *Tidabius*, a group proposed by R. V. Chamberlin in November of the same year (2, p. 80).

The typical series is comprised of a number presumably of conspecific individuals, cotypes, from which we have selected a female lectotype and male allolectotype, in our opinion the best preserved, mature specimens of the lot. The lectotype seems most closely related to *T. pallidus* Chamberlin (2, p. 92), from which it differs chiefly in the following characters. Antennal articles: *pallidus*, 27; *kansensis*, 29. Cephalic plate: *pallidus*, slightly wider than long (45.5:44); *kansensis*, as wide as long. Ocelli: *pallidus*, 1+431, 1+432; *kansensis*, 1+332, 1+321. Plectrotaxy of legs 10 and 11: *pallidus*, 00322/00231[3] *kansensis*, 00222/00231. We regard none of the foregoing interspecific morphological differences really convincing. As will be seen farther on, it is our suspicion either that *kansensis* is conspecific at least with *pallidus*, or that the plectrotaxic diagnostic characters so extensively used to date in this perplexing group by themselves are inadequate for delimiting the various species, if indeed a number of reproductively-isolated forms is involved.

We wish to express our thanks to Dr. A. B. Leonard of the University of Kansas for permitting us to study these specimens. Unfortunately they had been housed in a formalin solution for many years, with the result that many details of sculpturing, pilosity, and proportion are now obliterated or distorted.

Lectotype: female, Lawrence, Douglas County, Kansas; April 1912; "under

[1]Part I appeared in: Can. Ent., LXXXVII(5), pp. 221-223, (1955).

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[3]Dorsal and ventral spur formulae are shown to the left and right of the oblique, respectively.

the bark of old logs in damp weather"; Horace Gunthorp, leg. University of Kansas Collection, number 159.

Total length: 9.2 mm. Color: head and tergites tan to sordid yellow. Antennae: 2.6 mm. long; proximally darker than cephalic plate becoming lighter distally; each with 29 articles; second article slightly longer than first, equal in length to ultimate two taken together; pilosity denser distally. Cephalic plate: finely areolate; as long as wide; at midlength 1 mm. wide; sparsely setose. Eyes: major ocellus subcircular; six to eight smaller ocelli in three series, 1+332 (left), 1+321 (right); largest ocellus of first series only slightly smaller than major ocellus; organ of Tömösvary situated immediately anterior to foremost ocellus of lowest series. Prosternum: distinctly areolate; intercondylic distance to length of longitudinal suture, 39:23; with 2+2 teeth, these triangular, of equal size, a line through their apices slightly recurved; porodont setiform, longer than adjacent teeth apically very slightly incurved; diastema V-shaped, sides straight, vertex rounded. Tergites: very finely, shallowly punctate; sparsely, shortly setose; pedal tergite 13 weakly produced, 11 less so, 9 with square (not rounded) corners; ratio of tenth to first is 29:22; width-ratios of head to tergites 1,3,8,10, and 12 respectively 25,22,23,28,29,28. Sternites: becoming noticeably yellower at tenth sternite. Coxal pores: 3,4,4,4; circular; in each series the inner-most is smallest, the two outer-most with diameters subequal. Female gonopods: claw tridentate, middle tooth longest; basal spurs 2+2, straight and robust, basally with parallel sides, the distal half of each suddenly acuminate, all equal in length. Legs: first thirteen generally concolorous with associated tergites; none laterally armed; all tarsi distinctly divided, tarsal sutures of anterior legs complete except dorsally; legs 14 and 15 without lateral armature; length ratio of ultimate femur to ultimate tibia (from above) 16:18; ultimate and penultimate pretarsal claws flanked each by a small inner accessory claw; inner surfaces of ultimate and penultimate femora, tibiae, and tarsi cribrose as are corresponding surfaces on tibiae and tarsi of thirteenth legs.

Quantitative Plectrotaxy: 1=00111/00011; 2-7=00221/00021; 8=00222/00021; 9=00222/00131; 10+11=00222/00231; 12=00311/00231; 13=00311/01331; 14=00310/01331; 15=00200/01310. Qualitative plectrotaxy: DPA=12-14[4]; DPM=2-15; DPP=1-15; DFA=1-11; DFP=2-15; DTiA=1-11; DTiP=8-13; VTrM=13-15; VPA=13-15; VPM=9-15; VPP=10-15; VFA=2-14; VFM=1-15; VFP=9-14; VTiM=1-14; VTiA is entirely absent as a series.

Allolectotype: male; same locality data as for lectotype. This specimen differs from the lectotype chiefly in the following particulars. Length: 7.3 mm. Ocelli: 1+432; Quantitative plectrotaxy: 15=00200/01320; 13=00311/00311; 11=00322/00231; 10=00322/00231; 9=00222/00121; 7=00222/00021. Qualitative plectrotaxy: DPA=10-14; DTiP=10-14; VTrM=14-15; VPM=10-15; VPP=9—15; VFP=10—14. Cephalic plate: slightly wider than long (21.5:21). Antennae: right, 31 articles; left, broken.

Cotypes: same locality as above. As a group the remaining seven specimens generally are in very poor condition, many having lost legs, antennae, and other body parts. So far as we have been able to determine, and in our opinion, none differs specifically from the types described above. At the same time those specimens whose physical state permits any kind of diagnosis testify to a striking degree of intraspecific variability. This is especially apparent in plectrotaxy, a favored species criterion which in this group seems totally untrust-

[4]In each trio of letters the first is either D for dorsal, or V for ventral. The letter farthest to the right is either A for anterior, M for medial, or P for posterior. The central letter refers to a leg segment, viz. C=coxa, Tr=trochanter, P=prefemur, F=femur, Ti=tibia. Thus DPA=12-14 means that the dorsal prefemoral anterior spur occurs from legs twelve to fourteen inclusive.

worthy. Among the members of the series the following plectrotaxic variables were observed: 15V=013 1-2) 1[5], 14D=00 (2-3) 10; 13D=00 (2-3) 11; 13V= 0 (0-1) (2-3) (2-3) 1; 1D=00 (0-1) 11; IV=000 (0-1) 1.

The plectrotaxic variability observed in this series, together with that studied by the senior author in other forms congeneric with it, lead us to believe that quantitative plectrotaxy alone is inadequate for the definition of species and is, moreover, untrustworthy when employed as the *single* key criterion of a species or complex of species. We have encountered greater plectrotaxic latitude within the Gunthorp series than is discernible virtually in the entire genus, as presented in the 1913 treatment. Those forms currently referable to *Tidabius* in North America actually may be reducible to a highly variable and genetically unstable pair of species[6], or to a larger number of forms whose limits have not yet been accurately established.

The initial dichotomy in Chamberlin's 1913 key contrasts forms with a formula of 15V=01320 or 01330 (*poaphilus*, *anderis*, *bonvillensis*, *suitus*, and *nasintus*) with those having but a single ventral femoral spur, i.e. 15V=01310 (*tivius*, *opiphilus*, *pallidus*, and *p. alabamensis*). But within the Gunthorp series itself we find specimens assignable to each category; indeed, one specimen even displays 15V=01310 on one leg and 15V=01320 on the other.

This same asymmetry was encountered in each of three mature females collected recently within a hundred yards of each other in Saint Louis' Forest Park: all are obviously closely akin and evidently conspecific with *kansensis*. In each 15V right is 01310, and in each 15V left is 01320. Put in a different way, in each specimen the right fifteenth leg lacks VFA, and the left fifteenth leg retains VFA.

Although plectrotaxic asymmetries are not uncommon in lithobiids, they are found more consistently in immature specimens, and then they are characteristically haphazard. Two specimens of the same sex and age do not as a rule display precisely the same asymmetry. Possible immaturity of the specimens may be ruled out, for even though the full adult complement of spur series is established gradually during the latter anamorphic stadia, the most posterior definitive patterns are completed quite early, long before those of the anterior legs are finally stabilized.

We suggest that duplication of these identical asymmetries in all three of our specimens is indicative of a degree of genetic instability (for this character) of such magnitude to render this feature diagnostically impractical. This degree of instability in 15-VFA had heretofore been unknown to the senior author, although other variants of equal or greater magnitude, particularly in the anterior limits of certain ventral spur series, had been observed in other genera. In conclusion, we believe 15-VFA in *Tidabius* to be extremely unstable not only within the broad species perimeter, but even among immediate familials. If true, this would seem to pose serious objections for the continued use of *unqualified quantitative* plectrotaxy as a major basis of species definition, particularly within the *Tidabius* complex.

It should not follow from this that all plectrotaxic criteria are to be held suspect. There is considerable evidence supporting the diagnostic value of what might be termed *qualitative* plectrotaxy. By that we refer not to the number of spurs at a given locus, say on the ventral side of the tibia, but to the occurrence of a given spur linearly, from leg to leg, in other words *to the same*

[5]The item to the left of the equal sign refers to the fifteenth leg, ventral side. The formula to the right shows the following segment-spur associations: coxa, no spurs; trochanter, one spur; prefemur, three spurs; femur, one or two spurs, tibia, one spur.

[6]One of which might well be *bonvillensis* (1, p. 180), distinctive in possessing 3+3 basal spurs on the female gonopod.

spur's dispersion from its appearance on some anterior leg to its termination on some posterior leg. Then in qualitative plectrotaxy each spur is seen to be one member of a *serially homologous file* of identically located spurs. The importance of this approach was stressed and some of its terminology devised by Ribaut (6) whose contributions seem to have gone virtually unnoticed except by Henri Brölemann.

Although the presence or absence of an individual spur at a given locus (usually at the anterior or posterior limit of a series) is not always predictable and therefore is not always diagnostically reliable, the partial presence *or complete absence* of a spur series is usually highly predictable and diagnostically useful. It has already been demonstrated that the northeastern North American members of *Nampabius* can be grouped, and to an extent individually characterized, successfully on this basis (3).

Those *Tidabius* forms for which we have adequate plectrotaxic information are distinctive in that all lack series VTiA: the anterior ventral spur of the tibia occurs *on no leg.* As a series it is entirely absent. Here then is a distinctive, apparently constant, negative character applicable to this and, as we shall see, to other groups.

It is tempting to speculate upon its derivation, for which we might propose the following hypotheses. If this character is not a (1) manifestation of evolutionary convergency, having been independently acquired in different groups, it may be a (2) conservative character inherited in common by *Tidabius* and other allied groups. Inasmuch as there is presently no convincing generic arrangement of the world fauna, the second theory, if true, may involve a point of view that eventually could assist in the creation of a satisfactory generic system. It is impossible to explore the subject extensively here, but we feel that the following data–admittedly preliminary and limited–have some bearing on it.

In the United States the absence of VTiA is encountered in a number of apparently specialized lithobiids, notably in members of *Nampabius*, *Sigibius*, *Tidabius*, and some others. Many of these are dendrophiles, others inhabitants of the compact litter of the forest floor. All are small, obscure, of retiring habits (even for centipedes), and in one way or another seem morphologically distinctive. This spur series is also absent in *Taiyubius harrielae* (Chamb.) but not in its congeners. Since all occupy roughly the same kind of environmental niche, it seems not unreasonable to postulate an independent evolutionary loss of VTiA, that loss being the result of the imposition of similar selective pressures, of a subtle and unknown nature, upon quite different forms.

On the other hand the absence of VTiA is apparently concordant with an array of other characters which grouped typify a number of similar lithobiids. Not restricted geographically, this assortment includes among others the following: *melanops* Newport, *borealis* Meinert, *lapidicola* Meinert, *calcaratus* C. Koch, *duboscqui* Brölemann (*?=Sigibius puritanus* Chamb.), *Taiyubius harrielae* (Chamb.), and perhaps all of the Nearctic members of *Tidabius*. The first five are European (and are usually referred to *Lithobius*, s.l.), the others North American. Common to all are at least the following characters: the absence of VTiA; an elevated antennal number (25 or more); and a stable, low prosternal tooth number (2+2). It is conceivable that all represent closely related modern derivatives of some common and perhaps not remote ancestral pattern.

Objection could be raised that the tergites of these forms display a lack of conformity, for within the assemblage the tergites are variously produced. Thus in *melanops* and *harrielae* the ninth tergite is conspicuously produced, but it is not in the others. The inclination to associate in supraspecific groups forms

with identical or closely-similar tergital formulae has a precedent in the classical subdivision of *Lithobius* into subgenera on the basis of tergital production. However, close study of sectors of the richly varied Nearctic fauna seems to indicate that this criterion may often (though not, by any means, always) cut across natural groupings, e.g. genera or species groups. For example all of the North American forms assignable to *Paitobius* surely seem very closely related on the basis of a number of features, and yet these same forms exhibit a striking lack of interspecific tergital conformity. This and other examples infer the likelihood that within many groups of species differential tergital production can occur. This character may represent a parallel trend in many variously related groups of species and is perhaps a concomitant of a widespread, ancient evolutionary tendency toward body consolidation and contraction.

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Notes on a Laboratory Infection of Diptera Caused by the Fungus *Empusa muscae* Cohn[1]

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The signs of an *Empusa muscae* Cohn infection in dead flies were described over two centuries ago by de Geer (Kirby and Spence, 1826), who, however, attributed the cause to some factor other than a microorganism. Though the validity of the name *Empusa* has often been questioned, it is used in this paper following the suggestion by MacLeod (1956).

The following account deals with the transmission of *E. muscae* to species of Diptera under controlled laboratory conditions.

Natural Occurrence of the Disease in the Laboratory

The disease was introduced accidentally into the laboratory with field-collected specimens of *Servasia aculeata* (Ald.). It first became evident in laboratory-reared flies (species not recorded) 15 days after the diseased specimens of *S. aculeata* died. Six days later the effects of the disease were observed in five cages of *Kellymyia kellyi* (Ald.), and, in spite of caution used in handling diseased material, it continued to spread in the room until it was feared that the entire stock of dipterous parasites would become infected.

The disease spread only to cages covered with plastic screening; flies in cages covered with cheesecloth did not become infected. The apparent reason for

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this is that the loose fibers of the cheesecloth prevented entry of airborne conidiospores.

As a precautionary measure, to prevent further spread of the disease, all diseased material and all material that had been exposed to the disease was transferred to a large box in the rearing room. Flies from the few remaining cages were transferred to cages covered with cheesecloth. Flies were removed from these cages as soon as they showed any signs of infection, to reduce chances of release of conidiospores. These precautions apparently checked the spread of the fungus as only one further instance of the disease occurred in the room.

Identification and Study of the Causal Agent

The fungus that caused the laboratory infection was identified as *Empusa muscae* from the description given by Thaxter (1888) and was studied from adults of *K. kellyi* infected under controlled laboratory conditions.

A description of this fungus and its different stages was given by Thaxter (1888) and others. However, the following are some observations that have not been previously recorded: The protoplasmic coating on primary conidia acts as a protective agent against desiccation. This was shown by placing fresh conidia in a droplet of water on a glass slide, where the coating dissolved or washed off. When the water evaporated, the conidia did not complete the process of germination even, in most cases, if more water was added. The fact that primary conidia, unlike the secondary conidia, germinate even on a dry surface is important when considering the use of the fungus for microbial control of insects. Also, the secondary conidia are produced as sessile outgrowths from the walls of primary conidia whereas the tertiary are formed at the ends of germ tubes produced from the secondary conidia. The reason for such a difference is not known; however, it is possible that it may have some relation to the process of penetration of the host integument.

Artificial Transmission of the Disease in the Laboratory

Entomophthoreae are not transmitted readily in the laboratory (Thaxter, 1888). However, there have been reports of success by Speare (1912), Dustan (1924), Schweizer (1947), and Harris (1948). Several attempts by the author and his associates to transmit *Empusa grylli* Fres. failed.

The reasons for success or failure in transmission are not known in most instances. Temperature and humidity are important but there are no doubt other limiting factors. In the present study, the disease was active at a temperature of 75°F. and a relative humidity of 50 per cent. Natural light which passed through a frosted-glass window as well as clear glass in the box to which the diseased specimens had been transferred, was supplemented by a 15-watt fluorescent tube during daylight hours. However, for some unknown reason, the disease was almost immediately inactivated when the box was transferred to another room where the same conditions, except natural lighting, were provided. It is considered that some factor other than light was the critical one but, unfortunately, the disease could not be reactivated to investigate the possibilities.

Laboratory studies on the transmission of *E. muscae* were carried out in the large box to which the diseased specimens had been transferred. The flies were maintained and infected in small wooden cages with solid plastic fronts and plastic screen backs. The disease was transmitted from one insect to another by putting healthy flies (taken from cages outside the large box in which no disease was observed) into a cage with freshly dead flies from which conidiospores were being expelled. During the month that the disease remained active the infection

TABLE I
Mortalities of Three Species of Flies in Laboratory Transmissions of *Empusa muscae* Cohn Listed Serially

Source of inoculum	Species exposed	No. of flies tested	Age of flies	Days from exposure to death	Number dying	Percentage of total
Kellymyia kellyi	*K. kellyi*	25	18 days	8	4	16
				9	19	76
				10	1	4
				11	1	4
"	"	17	10 days	5	14	82
				6	3	18
"	"	30	7 days	5	25	84
				6	5	16
"	"	20	9 days	5	20	100
"	"	20	12 hours	4	5	25
				5	9	45
				6	6	30
"	"	20	12 hours	3	5	25
				4	13	65
				5	2	10
"	*P. affinis*	50	12 hours		0	
"	"	45	12 hours	12	6	13
				13	3	7
				14	4	9
"	"	10	1–2 days	7	1	10
				10	5	50
Pseudosar-cophaga affinis	"	55	2 days		0	
K. kellyi	*Musca domestica**	25	12 hours	7	3	12
"	"	50	12 hours	6	4	8
"	"	25	12 days		0	
"	"	25	12 days		0	

*All tests with *M. domestica* were started after the work was transferred to a new location.

was transmitted from *K. kellyi* to *Musca domestica* L. and *Pseudosarcophaga affinis* (Fall.), as well as from one specimen to another of *K. kellyi* (Table I).

Though the mortality records suggest that *K. kellyi* is more susceptible than the other two species, it is probable that, had the disease remained active, the mortality rates of *M. domestica* and *P. affinis* would have increased to the same extent as that of *K. kellyi* through continued exposure to the disease. Also, the virulence of the fungus increased with increased passage through insect hosts; this is shown by the shortening of the period from exposure to death and also by the increase in mortality. The experiments with *K. kellyi* suggest that the age of the fly is not related to its susceptibility to infection.

Signs of Infection

A fly infected with *E. muscae* shows definite signs of a disorder about 12 hours before death in that it becomes somewhat sluggish and reacts slowly to

external stimuli. A short time later, it loses its ability to fly and walks aimlessly about the cage. As a rule, about two hours before death the fly climbs slowly upwards and then attaches itself by the proboscis to the side or top of the cage. After death, the abdomen swells considerably, exposing the intersegmental membranes. The conidiospores penetrate these membranes, giving the abdomen a banded appearance. In a very short time, the conidiospores are discharged, as evidenced by a white ring about three-quarters of an inch in diameter that forms around the fly.

Attempt to Obtain Translarval Transmission

A debatable subject in insect pathology is the possibility of translarval or transovarial transmission of pathogenic microorganisms. To determine whether this could occur in *E. muscae*, gravid females of *K. kellyi* were exposed to the disease and examined after death for the presence of the fungus, as well as for living young. All but four of the flies died before the larvae had developed fully. These flies were dissected and the larvae removed and placed on freshly killed grasshoppers on moistened filter paper in a petri dish. The larvae entered the grasshoppers almost immediately. After the first day, the larvae were transferred to pork liver, on which they were reared to maturity by the method of Mr. R. W. Smith (verbal communication) of the Belleville laboratory. At maturity, the larvae were transferred to sawdust to pupate.

There were 131 mature larvae. Of this number, 108 pupated and 100 developed to adult flies. The larvae and pupae that did not develop were examined microscopically but showed no evidence of the fungus disease. The emerging flies were kept in cages, as described above, until they died. Careful examination of the flies shortly after death revealed no evidence of infection by *E. muscae*. Therefore, it was concluded that *E. muscae* did not pass from one generation of flies to another by translarval transmission.

Summary

A laboratory infection of *Empusa muscae* Cohn was accidentally initiated when field-collected adults of *Servasia aculeata* (Ald.) were put into a room with other dipterous parasites of grasshoppers. The disease was stopped in the room by removing all material suspected of being diseased and by the use of aseptic techniques and of cages covered with cheesecloth. The fungus was identified from *Kellymyia kellyi* (Ald.) and was transmitted under controlled laboratory conditions from this species to *Pseudosarcophaga affinis* (Fall.) and *Musca domestica* L. The disease became inactive when the material was transferred to another room that had the same conditions of temperature and humidity. The reason for this is not known. As translarval transmission of *E. muscae* did not occur, the disease must pass indirectly from one generation of flies to another.

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Book Review

BEITRAGE ZUR SYSTEMATIK DER LARVEN DER ITONIDIDAE. (=CECIDOMYIIDAE), DIPTERA, 1. Teil: Porricondylinae und Itonidinae Mitteleuropas, by Edwin Möhn; 247 pp., 30 pls. Zoologica, 38, Heft 105, Lieferungen 1 and 2, 1955.

Until now our knowledge of the taxonomy of gall midge larvae has been due largely to the work of two men—J. J. Kieffer and E. H. Rübsaamen. The work under review indicates that a third major contributor has appeared. Unlike the other two, each of whom climaxed a long series of mostly shorter papers with a major work, the present author has produced, as his initial contribution, an extensive and thorough monograph.

The descriptive portion of the work is preceded by discussions of rearing and mounting techniques, of anatomical features and of larval habitats. Of particular interest is a detailed discussion of the relationships of the various genera as indicated both by external anatomy and by habitats.

The bulk of the paper consists of detailed descriptions, from specimens, of the larvae of 160 Central European Itonididae belonging to 112 genera. Descriptions of 13 additional species of as many genera are included from the literature. Only 22 of the species are described for the first time, but many of the previous "descriptions" were no more than brief statements concerning the shape of the breastbone; the uniform descriptions given here will be of great value. The 362 figures are semi-diagrammatic, but are large, clear and apparently quite adequate. References to previous descriptions and figures of the larvae described are included. Type species of the genera treated are indicated; the author, with admirable restraint, has refrained from designating types himself, but he would have saved future workers much trouble had he given the authority for the type species already designated.

The descriptions are followed by a key to the four subfamilies of the Itonididae and to the genera of the two subfamilies treated here, an extensive list of references, and an index of generic and specific names.

The author seems a little presumptuous in stating that larvae of members of the tribes Oligotrophidi, Asphondilidi and Lasiopteridi have already utilized almost all reduction possibilities and that a development of new forms is not to be expected. The nature and course of future evolution would seem to be beyond the knowledge of anyone.

This is undoubtedly the most detailed and thorough major work on gall midge larvae yet to appear. It is to be hoped it will provide an impetus to a study which has been badly neglected since the publication, in 1938, of Rübsaamen's last paper.

J. R. Vockeroth.

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